2015 HWRFV9.0.0 Implementation Briefing to EMC:

Much improved and higher resolution (2km) operational forecast guidance for all global tropical cyclones

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in collaboration with
NHC, DTC, GFDL, URI, UCLA, Purdue/NSF, HRD

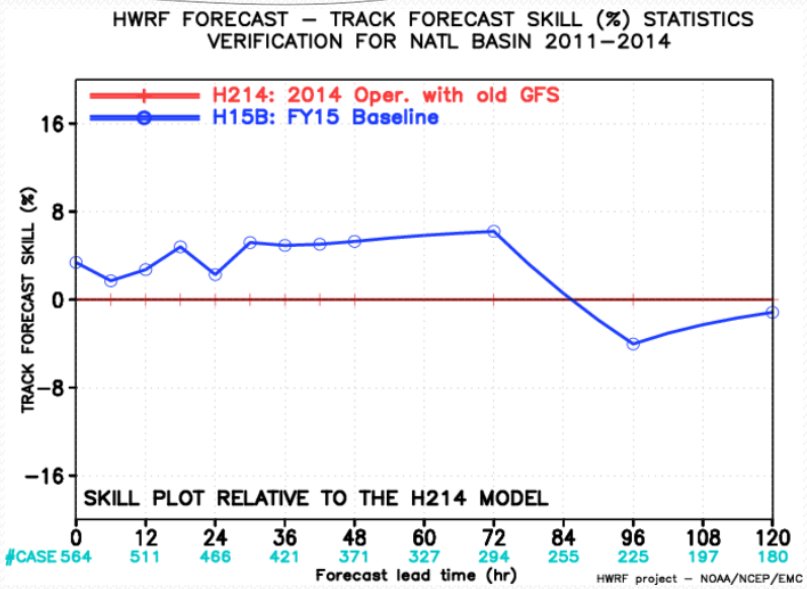
EMC CCB Meeting, April 15, 2015

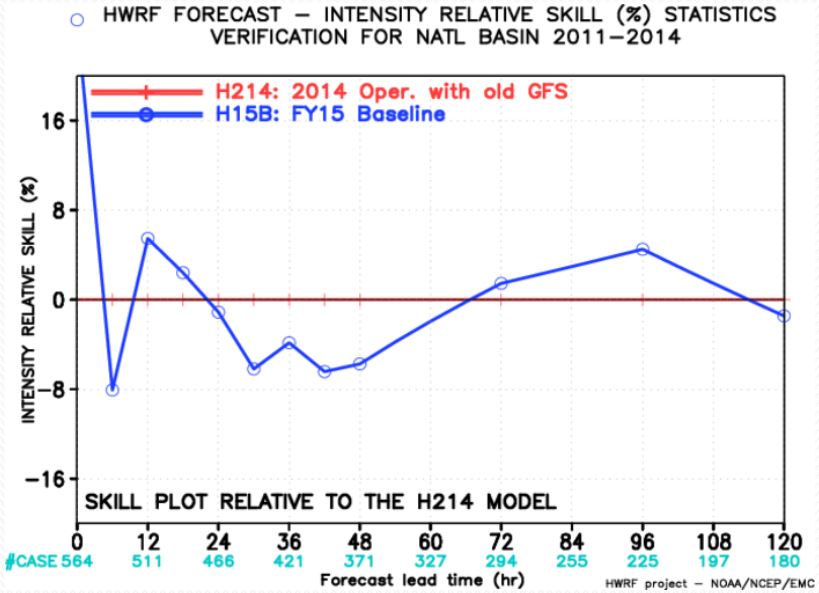
Scope of FY15 HWRF Upgrades

- **System & Resolution Enhancements**
  - Replace current partial HWRF python based scripts with complete Python based scripts for a unified system
  - GFS data Upgrades
  - *Increase the horizontal resolution of atmospheric model for all domains from 27/9/3 to 18/6/2 km.*
- **Initialization/Data Assimilation Improvements**
  - Upgrade and improve HWRF vortex initialization scheme in response to both GFS and HWRF resolution increases
  - Upgrade Data Assimilation System with hybrid HWRF-based EnKF and GSI system.
- **Physics Advancements**
  - Upgrade Micro-physics process (Ferrier-Aligo)
  - Upgrade GFDL radiation to RRTMG scheme with partial cloudiness
  - Upgrade surface physics and PBL, momentum and enthalpy exchange coefficients(Cd/Ch)
  - Upgrade current GFDL slab model to NOAH LSM.
- **First time in 2015….**
  - *Self cycled HWRF ensembles based warm start for TDR DA*
  - *Expand HWRF capabilities to all global (including WP/SH/IO) basins through 7-storm capability in operations to run year long*

HWRF Infrastructure/Resolution Upgrades

- The NMM core of the operational HWRF model upgraded to latest community version WRF V3.6.1.
- The horizontal resolution increased from 27/9/3km to 18/6/2km, which allow the model to resolve more storm scale features and have better storm-large scale interactions.
- Use high resolution GFS T1534 as IC/LBC
- Fix a major bug in vortex initialization for tropical storms in Southern Hemisphere
- Adjust the size of the filter domain in response to res. GFS res. increase
- Add more smoothing if the radius of maximum wind speed is significantly smaller than observation
- Remove the basin-dependence in vortex initialization





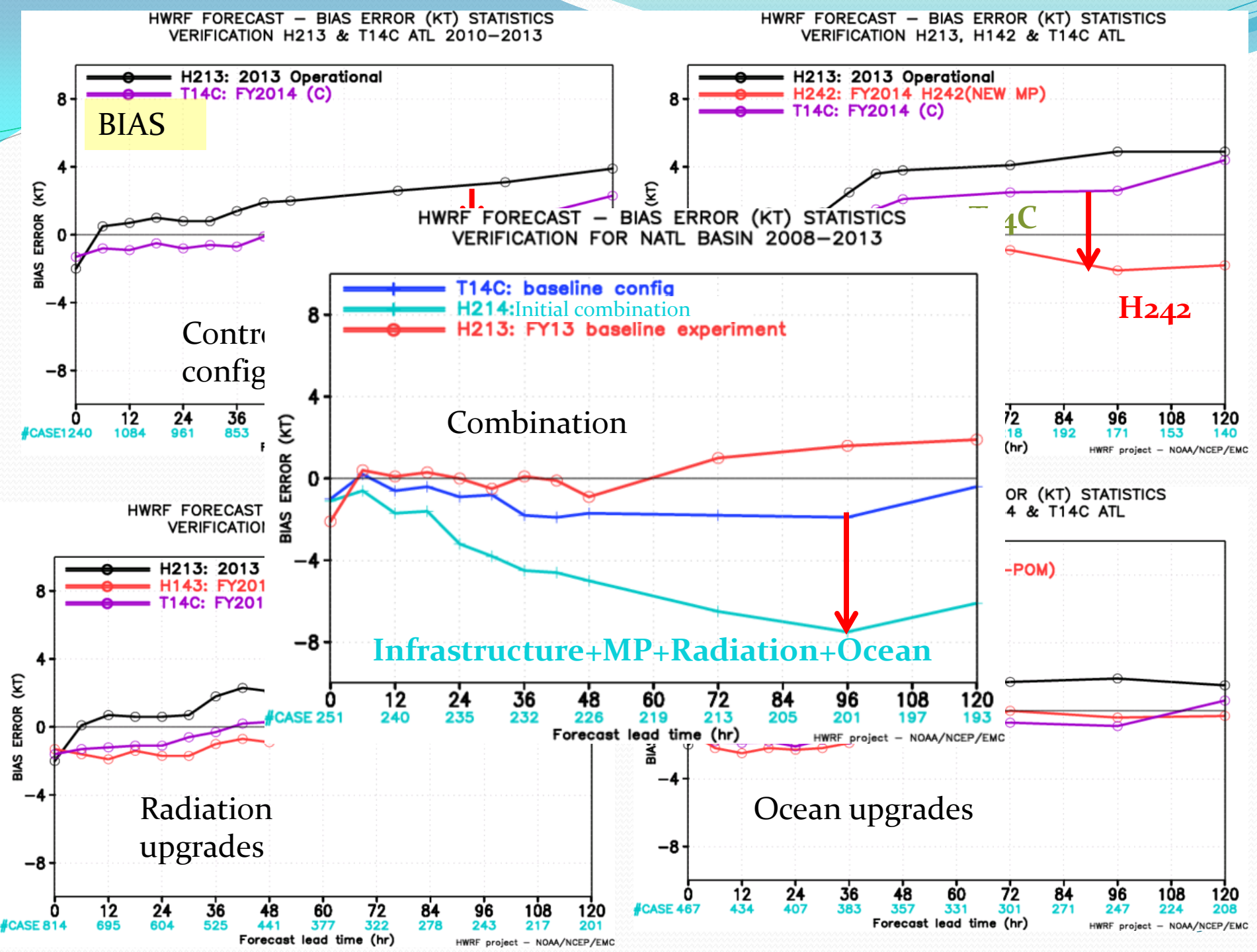
Data Assimilation Upgrades (H15T)

- DA Upgrades for non-TDR cases (included in H215)

  - Upgrade to the latest EMC GSI v5.0.0, and further tuned to improve the initial analysis for all HWRF domains.
  - use the 80-member global ensemble based one-way hybrid EnKF-3DVAR 6h forecast fields to calculate the covariance.
  - Enlarged d2 (6km) and d3 (2km) analysis domains to address discontinuity in the initial condition between forecast domains;
  - Run GSI on d2 analysis domain and add analysis increment to d3;
  - No satellite DA on d3 analysis domain due to pronounced negative impact;
  - Added the assimilation of tcvitals MSLP data along with all dropsonde data.

- DA Upgrades for TDR cases (H215 Final):

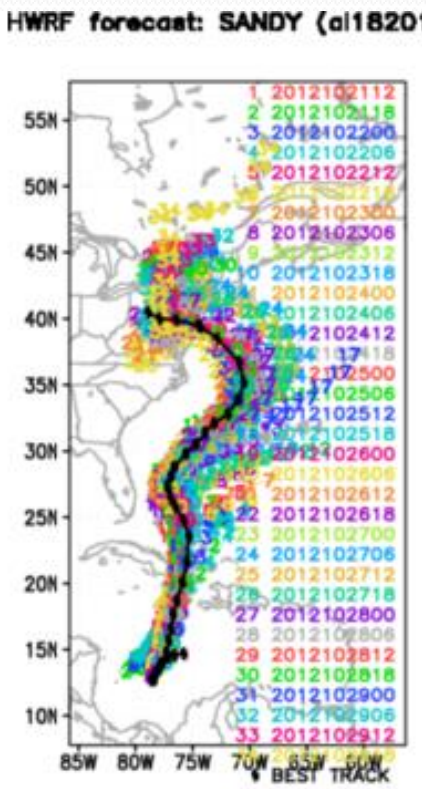
  - run 40-member HWRF ensembles for 6h to provide more accurate, flow-dependent, vortex-dependent data assimilation covariance.
  - Run GSI on both d2 and d3 analysis domains;
  - Larger data assimilation domains


HWRF FORECAST – BIAS ERROR (KT) STATISTICS
VERIFICATION H213 & T14C ATL 2010–2013
H213: 2013 Operational
T14C: FY2014 (C)
BIAS
BIAS ERROR (KT)
#CASE1240 1084 961 853
HWRF FORECAST – BIAS ERROR (KT) STATISTICS
VERIFICATION H213, H142 & T14C ATL
H213: 2013 Operational
H242: FY2014 H242(NEW MP)
T14C: FY2014 (C)
H242
HWRF project – NOAA/NCEP/EMC
HWRF FORECAST – BIAS ERROR (KT) STATISTICS
VERIFICATION FOR NATL BASIN 2008–2013
T14C: baseline config
H214:Initial combination
H213: FY13 baseline experiment
Combination
Infrastructure+MP+Radiation+Ocean
#CASE 251 240 235 232 226 219 213 205 201 197 193
Forecast lead time (hr)
HWRF project – NOAA/NCEP/EMC
HWRF FORECAST
VERIFICATIO
H213: 2013
H143: FY201
T14C: FY201
Radiation upgrades
#CASE 814 695 604 525 441 377 322 278 243 217 201
Forecast lead time (hr)
HWRF project – NOAA/NCEP/EMC
Ocean upgrades
#CASE 467 434 407 383 357 331 301 271 247 224 208
Forecast lead time (hr)
HWRF project – NOAA/NCEP/EMC

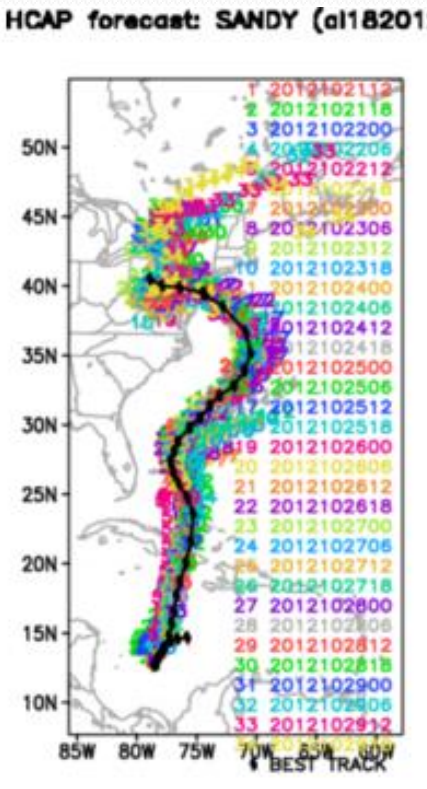
Upgraded Land Surface model

GFDL slab to NOAH LSM – NSF VSP Contributions

- NOHA LSM provides realistic land surface physics, and predicts soil moisture, soil temperature, land surface skin temperature, land surface evaporation and sensible heat flux, and total runoff.
- NOAH LSM significantly reduced the negative temperature bias
- **A major bug fix for NOAH LSM is introduced to prevent occasional model crash due to inconsistent stability dependent heat exchange coefficients over land *(Subramaniam, NSF-NOAA VSP)***
- HWRF will include additional products for down-stream applications (e.g. storm surge, inland flooding)
- Track errors for land-falling storms are improved based on preliminary tests



GFDL Slab

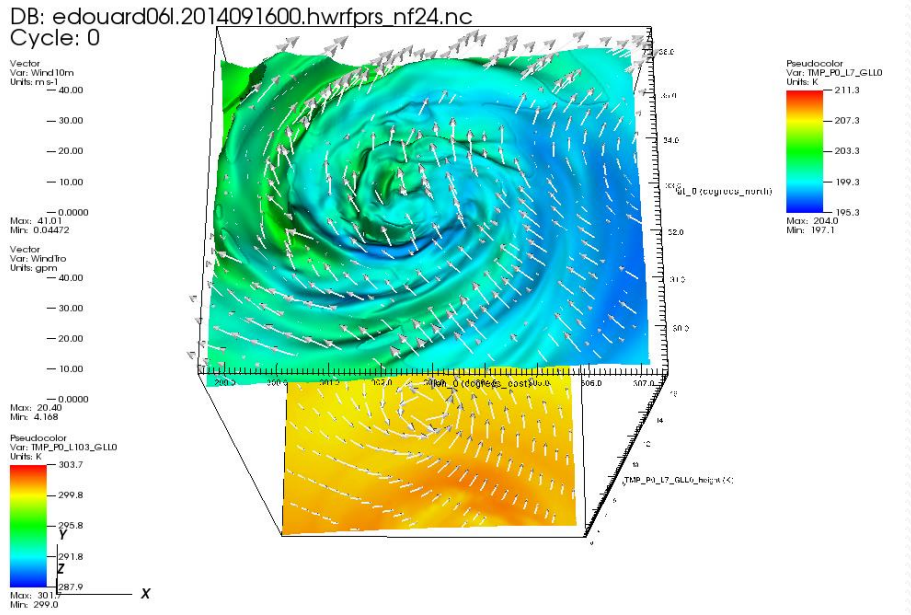


NOAH LSM

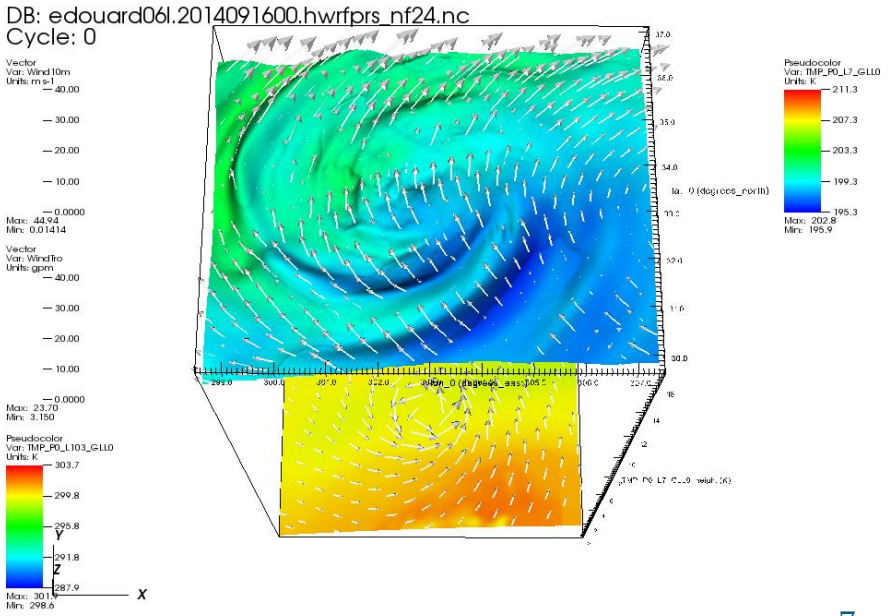
Upgraded Hi-Res Ferrier-Aligo Microphysics
Contributions from EMC MMB (Ferrier & Aligo)

1. New ice nucleation scheme to reduce no. concentration of small ice crystals
2. New, simpler closure for diagnosing small ice crystals and large, precipitating ice particles from ice mixing ratios
3. Slightly slower fall speeds of rimed ice
4. Increase the maximum (minimum) number concentration of small (large) ice in order to simulate better anvil cloud

With upgraded Ferrier, High-Res



H214 Current Ferrier

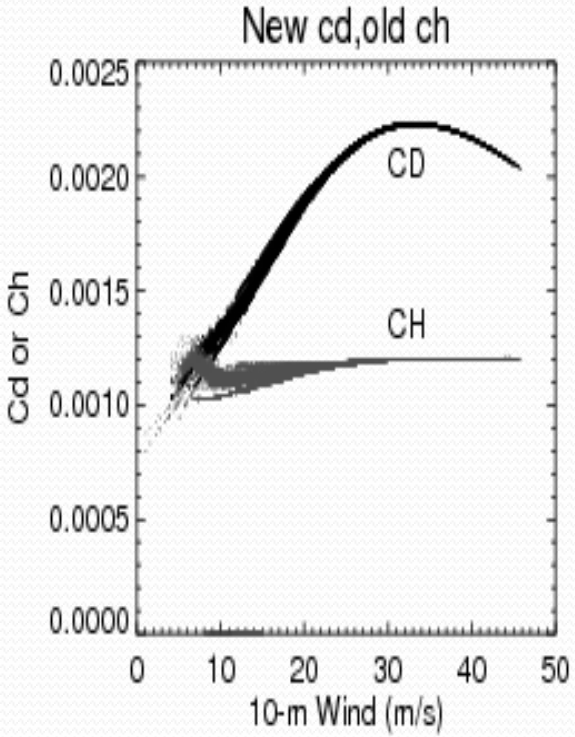


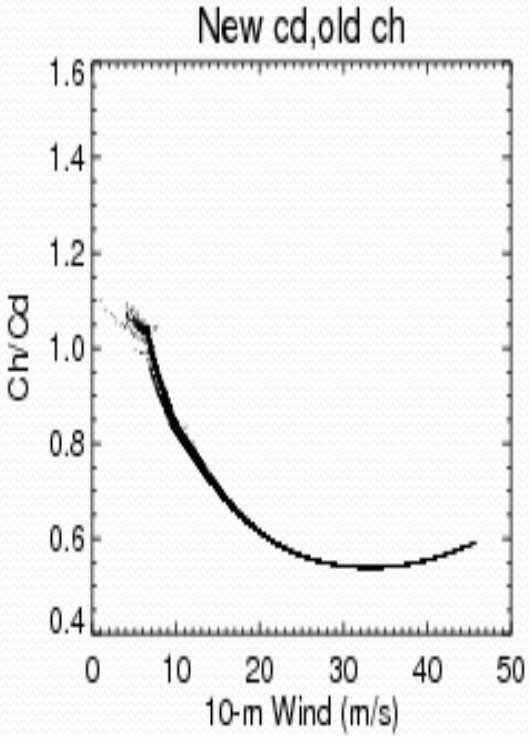
Individual test showed positive impacts on structure and intensity forecasts

Upgraded surface physics

(revised momentum exchange coefficient with inputs from GFDL/URI)

Cd/Ch change, suggested by URI, to better match observations values. The modified configuration provides improved intensity bias.



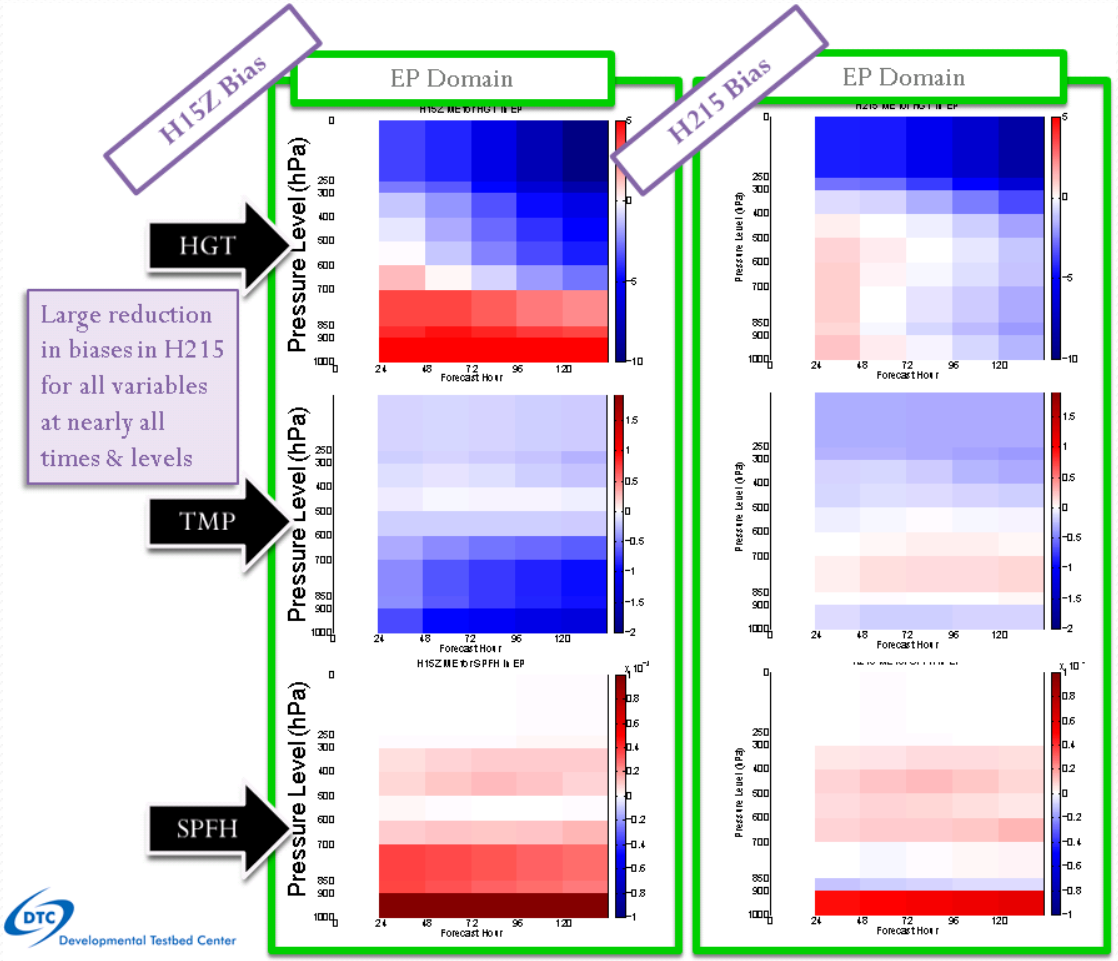


Increase of Ch at higher wind speeds (as implemented in GFDL) was causing model to become unstable and crash for stronger storms, suggestive of strong dependency of heat exchange coefficients at air-sea interface on model horizontal resolution

Upgraded SW/LW radiation schemes and PBL

GFDL radiation to RRTMG with sub-grid-scale cloudiness (Contributions from DTC, NCAR and UCLA)

1. GFDL radiation schemes have problems of proper representations of cloud-radiation interactions, especially net cloud top cooling and net cloud base warming.
2. Introduced much improved RRTMG radiation with parameterized sub-grid scale cloudiness and variable alpha (wind-speed dependent) vertical mixing coefficient (following work done by Robert Fovell, UCLA; Greg Thompson, NCAR; Ligia Bernardet/Christina Holt, DTC).



Dramatic Reduction in biases for Height, Temperature and Specific Humidity

Identified a problem in RRTMG related to O_3/CO_2 initialization. Fixed in final H215 configuration

Code Optimization & Workflow Modifications

- Sped up 2015 HWRF from 160 minutes to 96 minutes
  - Increase from 13 compute nodes to 22 (~2.5x increase w.r.t. WCOSS Phase 1 16 core nodes, to fit of new 24 core Phase 2 compute nodes).
  - Change the task geometry so that WRF compute processors within one compute node are adjacent to one another in a 4x4 grid.
  - Switch to the quilt_pnc implementation of WRF I/O servers. This gained us about 30-35 minutes of runtime.
  - Turn off the logging from all WRF processors. This gained us about 8 minutes of runtime.
- End-to-end HWRF scripting system in Python for all global ocean basins
- Switch to 100% GRIB2 output from HWRF
- Further changes to the HWRF workflow to improve the timing and reliability of forecast delivery
- New procedures for SDM to launch HWRF and GFDL separately

Q3FY15 Hurricane WRF V9.0.0

Project Status as of 03/06/2015

Project Information and Highlights

Lead: Vijay Tallapragada, EMC and Becky Cosgrove, NCO

Scope:

1. Replace current partial HWRF python based scripts with complete Python based scripts for a unified system.
2. Increase the horizontal resolution of atmospheric model for all domains from 27/9/3 to 18/6/2 km.
2. Upgrade and improve HWRF vortex initialization scheme in response to both GFS and HWRF resolution increases.
3. Upgrade Data Assimilation System with hybrid HWRF-based EnKF and GSI system.
4. Upgrade model physics to accommodate model resolution increase, including micro-physics process, radiation, surface physics and PBL.
5. Upgrade current GFDL slab model to NOAH LSM.
6. ~~Upgrade ocean initialization for MPIPOM~~
7. Self cycled HWRF ensembles based warm start for TDR DA
8. Expand HWRF capabilities to all global (including WP/SH/IO) basins through 7-storm capability in operations to run year long

Expected Benefits:

1. Improved track & intensity forecast skill and additional model output for

downstream applications

Scheduling

Milestone (NCEP)	Date	Status
Initial coordination with SPA team	1/31/2015 → 3/13/2015	Complete
EMC testing complete/ EMC CCB approval	3/31/15 →4/15/2015	
Final Code Delivered to NCO	3/28/2015 → 4/09 →4/16/2015	
Technical Information Notice Issued	3/17 → 4/29/2015	
Initial Test Complete	4/30 → 5/15 → 5/22/2015	
Test with specific cases	4/17 → 4/24 →4/30/2015	
Testing Ends	4/24 →5/04 → 5/11/2015	
IT testing ends	5/05 → 5/15/2015	
Management Briefing	5/09 → 5/25/2015	
Operational Implementation	5/25 → 5/26/2015	

Issues/Risks

Issues:

Risks:

Mitigation:

Finances

Associated Costs:

Funding Sources: EMC Base: T2O 18 Man-months (3 FTE full time for 6 months). NCO Base: 2 man-months for implementation, 1 man-month annually for maintenance

R	Management Attention Required	Y	Potential Management Attention Needed	G	On Target

HWRF Upgrade Plan for 2015 Implementation

Multi-season Pre-Implementation T&E

	GFS Upgrades	Model upgrades	Physics and DA upgrades				Combined
	Control (H15Z)	**Baseline (H15B)**	**NOAH LSM (H15W)**	**Upgraded Ferrier (H15W)**	**RRTMG/ PBL/ Surface Physics (H15W)**	**DA* (H15T)**	**H215**
Description	Create a new control configuration of 2014 Operational HWRF run with newly upgraded GFS T1534 IC/BC	1.Resolution increase: 18/6/2km w/ same domain size; 2. Python scripts 3. New GFS T1534 4. Init improvement, GFS vortex filter	NOAH LSM (w/ Ch cap over land)	Separate species, w/o advection	1.Radiation 2.Variable α 3.Scale-aware partial cloudiness scheme	Hybrid GSI/ HWRF-EPS based DA	Baseline + NOAH/LSM +newMP+RRTMG+ Surface Physics + PBL + DA changes
Cases	Four-season 2011-2014 simulations in ATL/EPAC, cases (~2300)	Four-season 2011-2014 simulations in ATL/EPAC, cases (~2300)	Priority cases	Priority cases	Priority cases	Only TDR cases for 2011-2014	Four-season 2011-2014 simulations in ATL/EPAC, cases (~2300) WP/SH/IO 2013-2014 (~1200 cases)
Platforms	Jet/WCOSS	Jet	WCOSS	Jet	Jet/Zeus	Jet	Jet/WCOSS/Zeus

The plan is based on the assumption that 2015 operational HWRF system will have 3x computer resources within the HWRF operational time window. We will be using only 2.5X for each storm

**** DA experiment requires additional computer resources outside current operational time window.***

Acronyms

- **H214**: 2014 version of operational HWRF, 27/9/3km resolution, L61, input: T574 L64 GFS (Spectral files for both IC and BC);

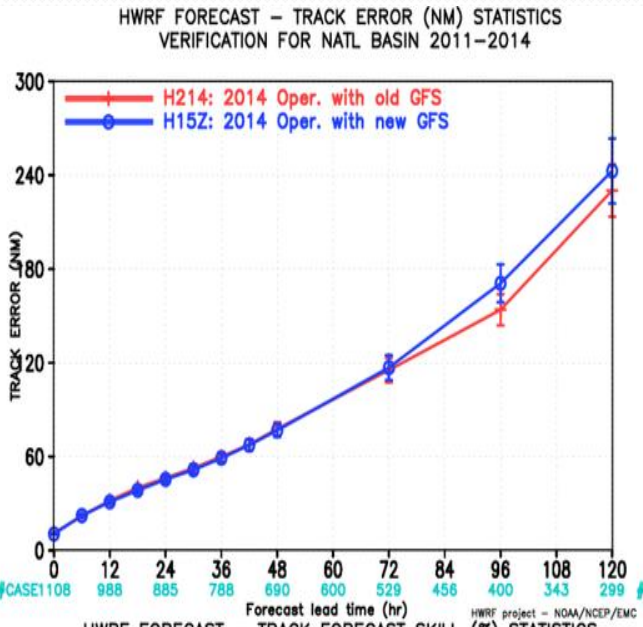
- **H15Z**: H214 driven by New GFS (Control)

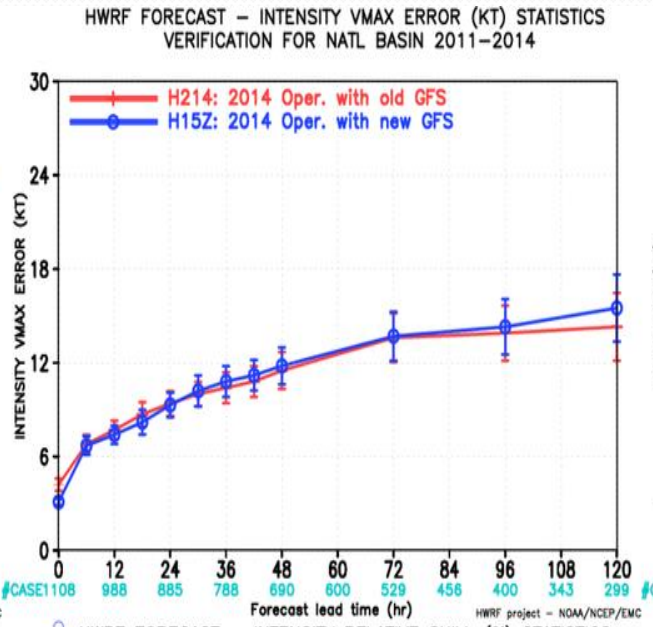
- **H15B**: FY15 HWRF baseline, 18/6/2km resolution, L61, input: T1534L64 GFS (Spectral files for both IC and BC);

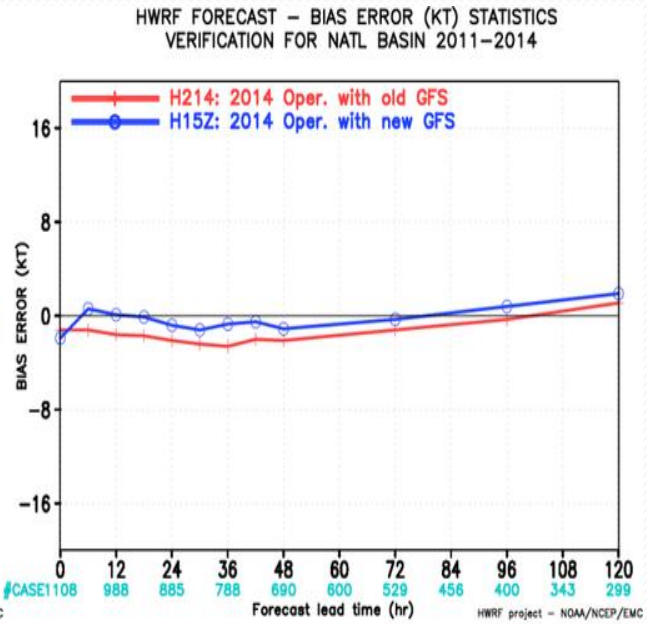
- **H215**: H15B + All Physics + DA upgrades;

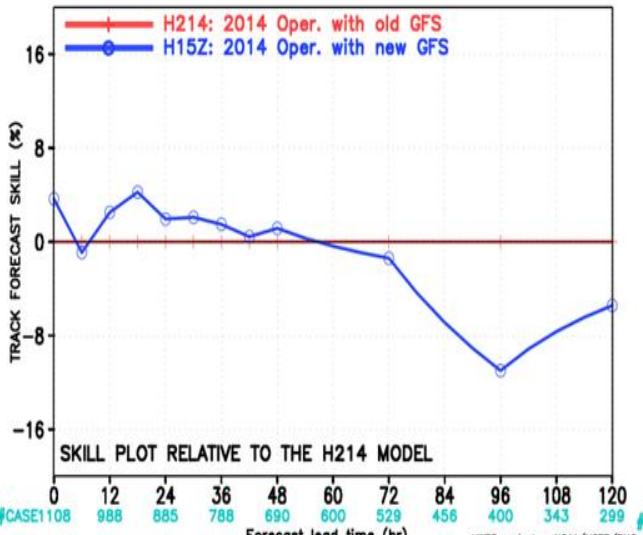
Verification for Atlantic Storms (2011-2014)

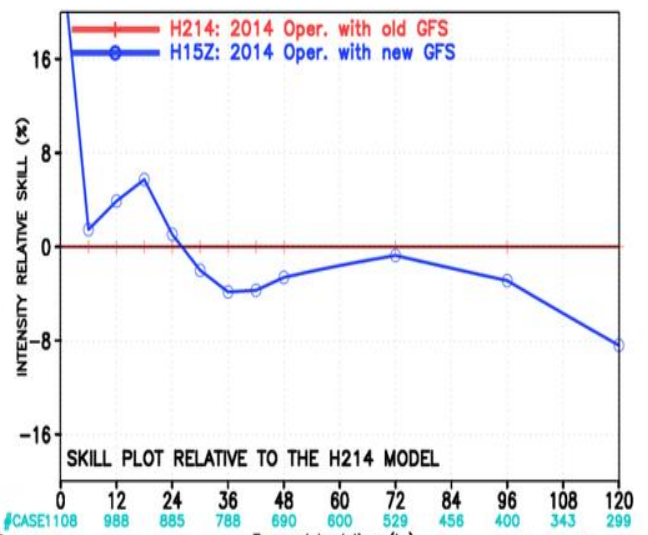
Impact of New GFS, NATL, 2011-2014





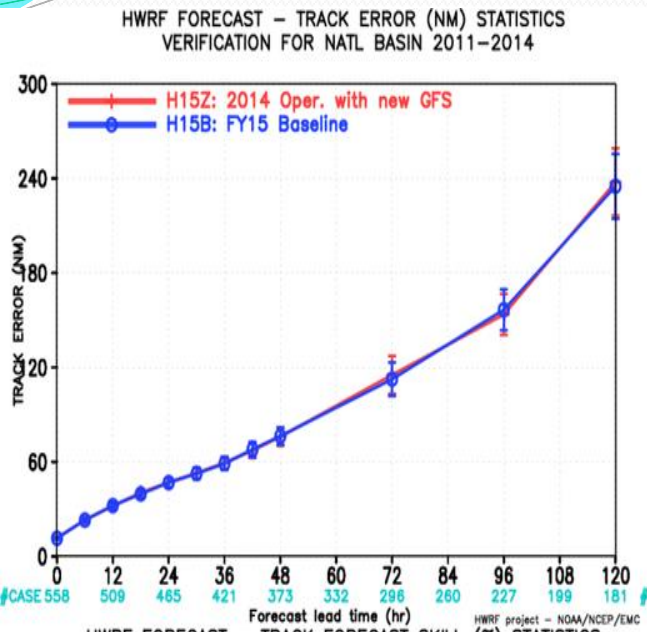


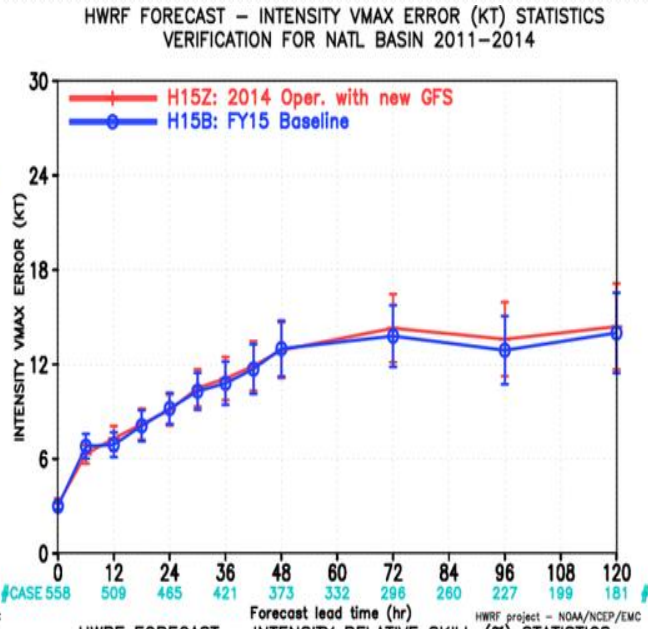


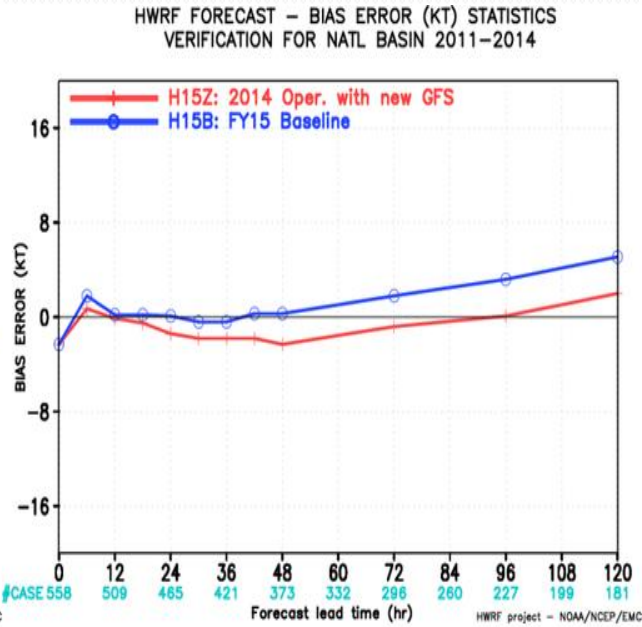


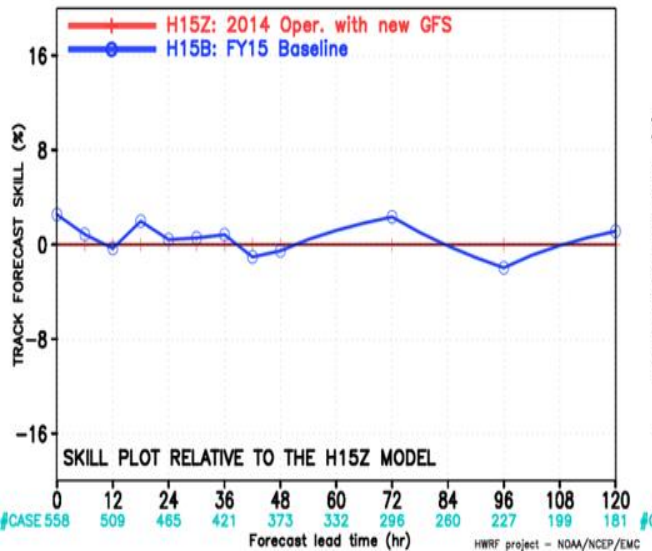
New GFS degraded track/intensity forecasts in the Atlantic Basin

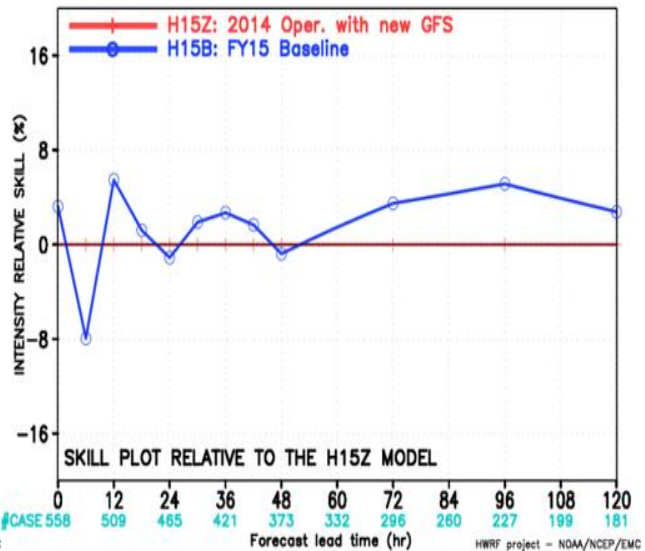
Impact of HWRF Resolution Increase, NATL, 2011-2014









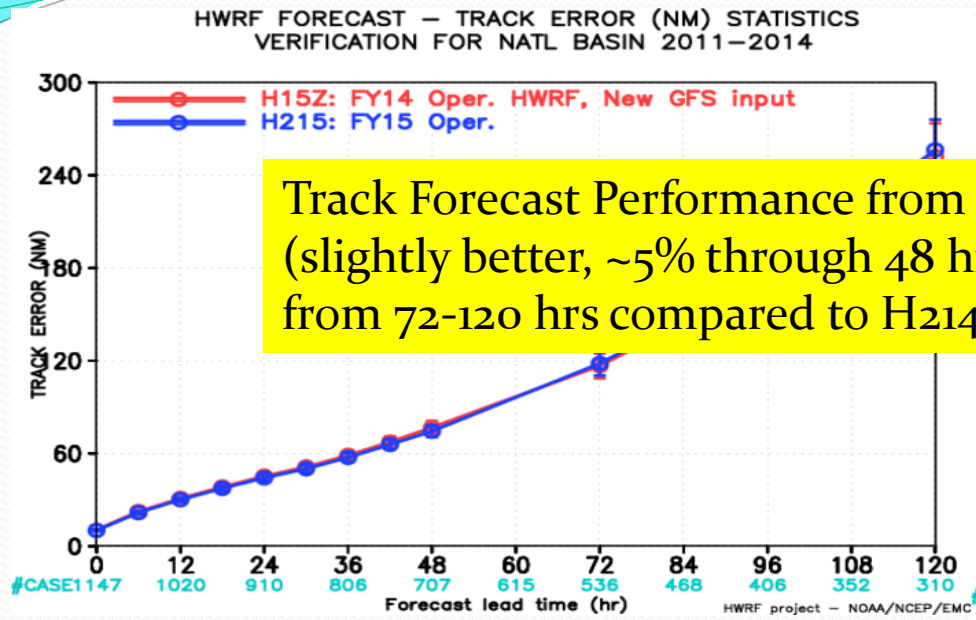


Neutral track impact;
Neutral to positive intensity impact;
Relative large intensity bias;

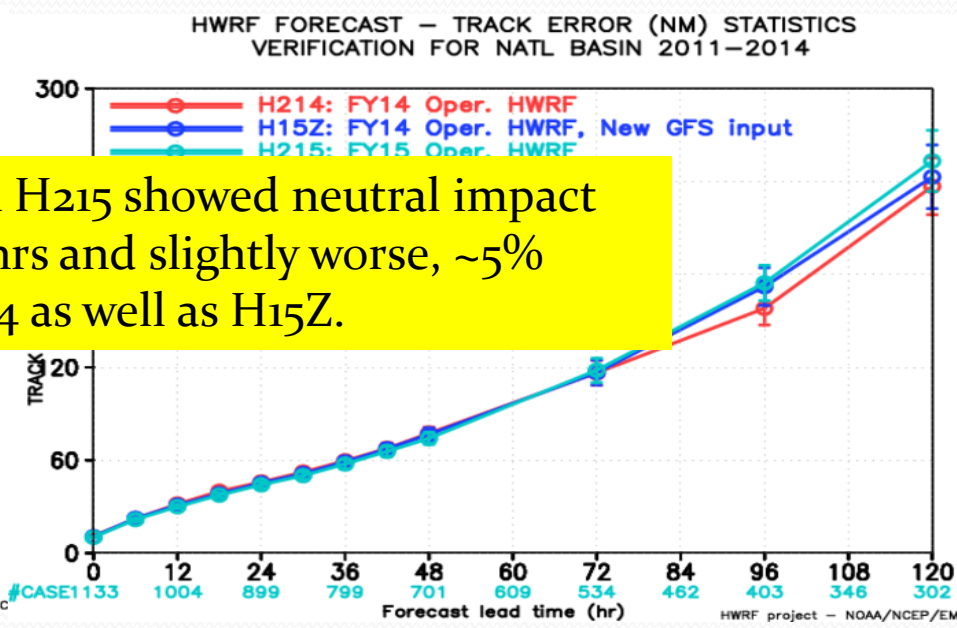
Resolution upgrades and vortex initialization changes have offset the loss of skill due to new GFS

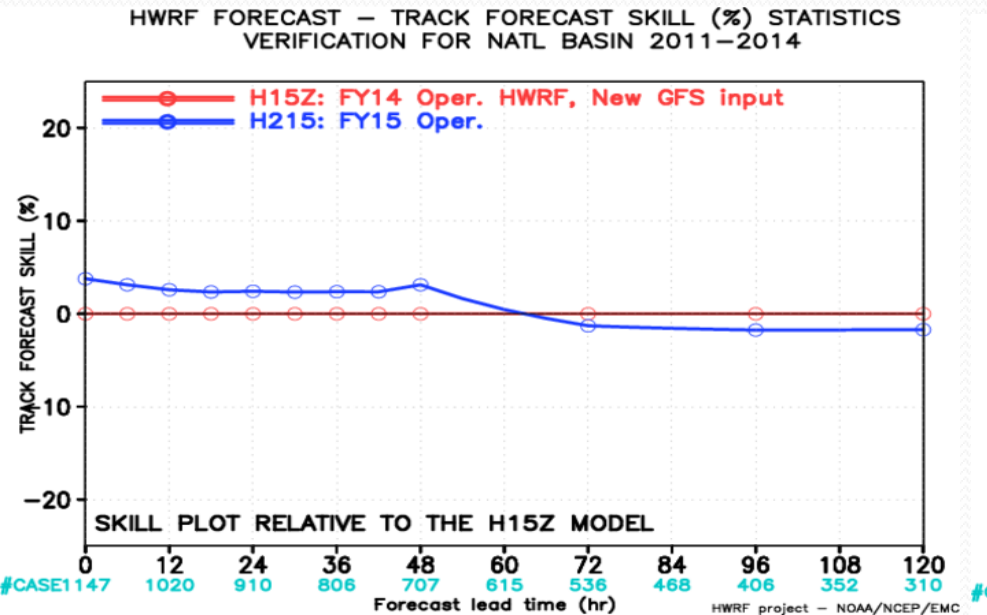
Impact of Physics, Resolution & New GFS, (H215 vs H15Z & H214)

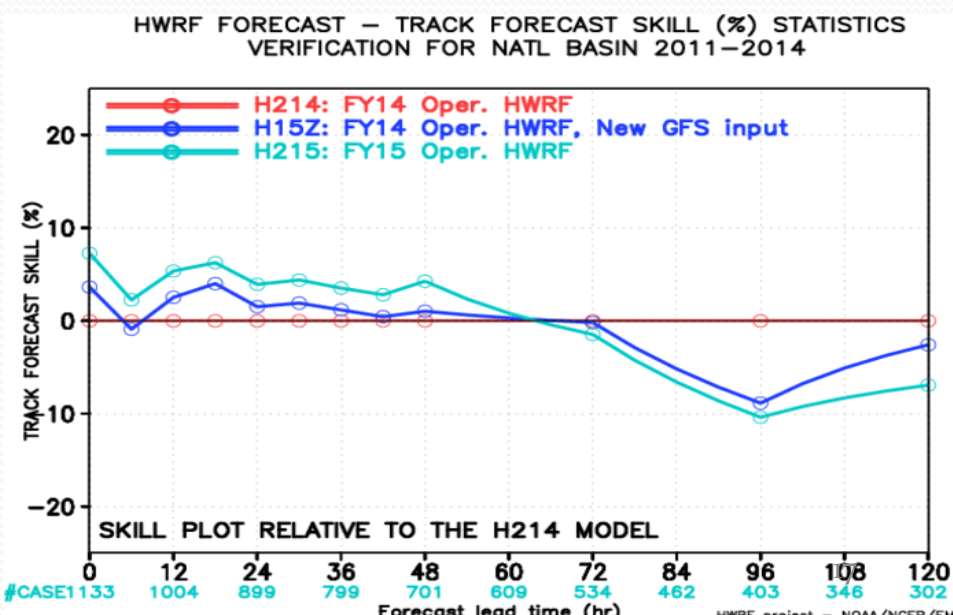
NATL Track Forecasts 2011-2014



Track Forecast Performance from H215 showed neutral impact (slightly better, ~5% through 48 hrs and slightly worse, ~5% from 72-120 hrs compared to H214 as well as H15Z.

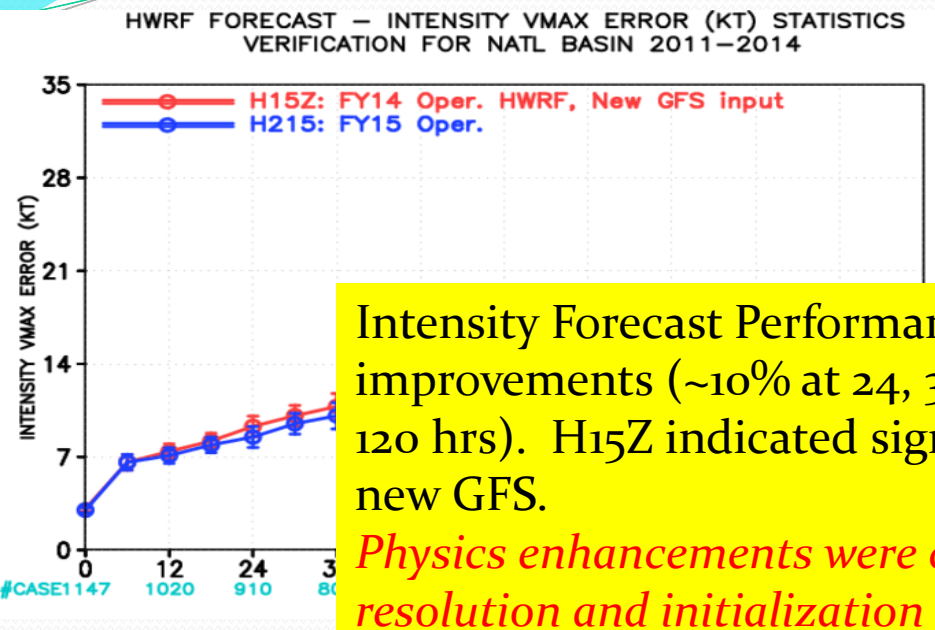


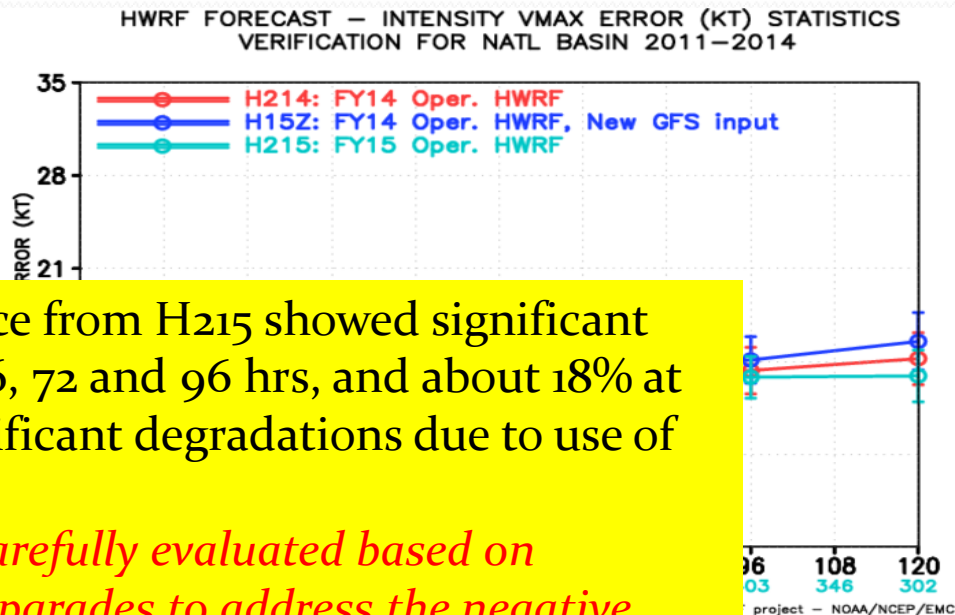




Impact of Physics, Resolution & New GFS, (H215 vs H15Z & H214)

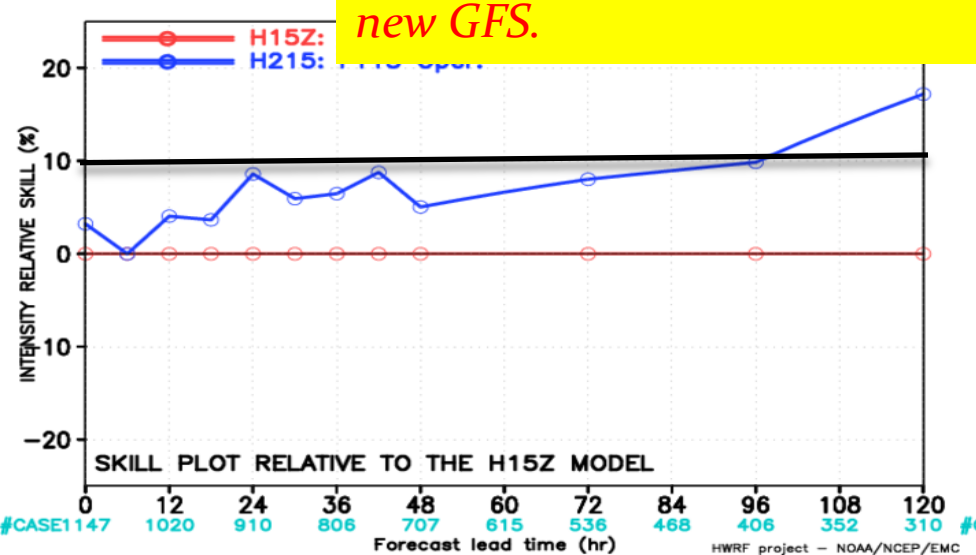
NATL Intensity Error Forecasts 2011-2014

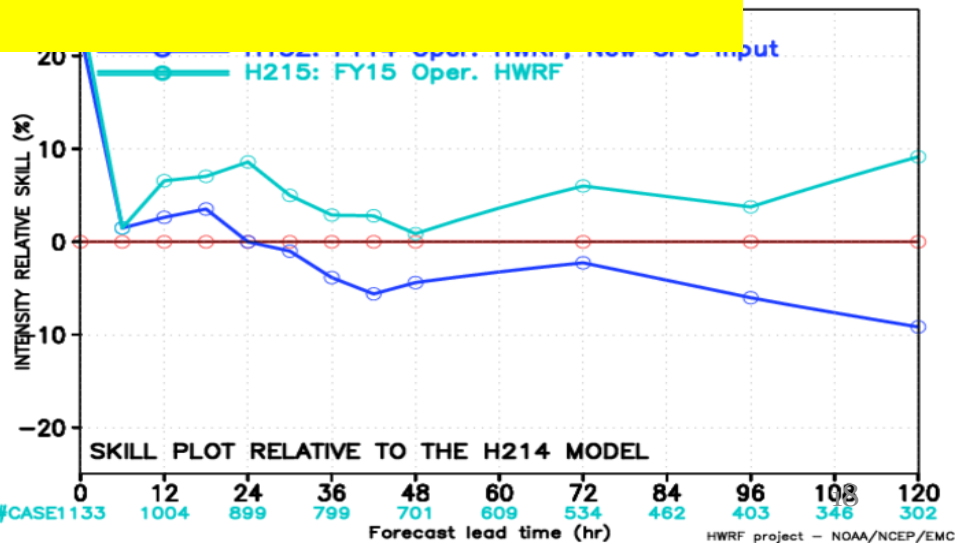




Intensity Forecast Performance from H215 showed significant improvements (~10% at 24, 36, 72 and 96 hrs, and about 18% at 120 hrs). H15Z indicated significant degradations due to use of new GFS.

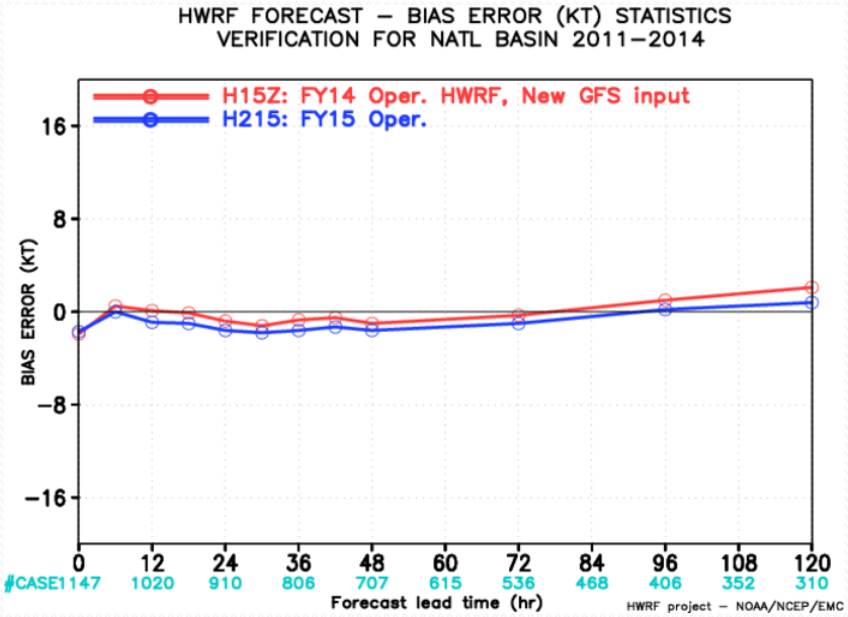
Physics enhancements were carefully evaluated based on resolution and initialization upgrades to address the negative impacts noted in H214 evaluation as well as degradations due to new GFS.

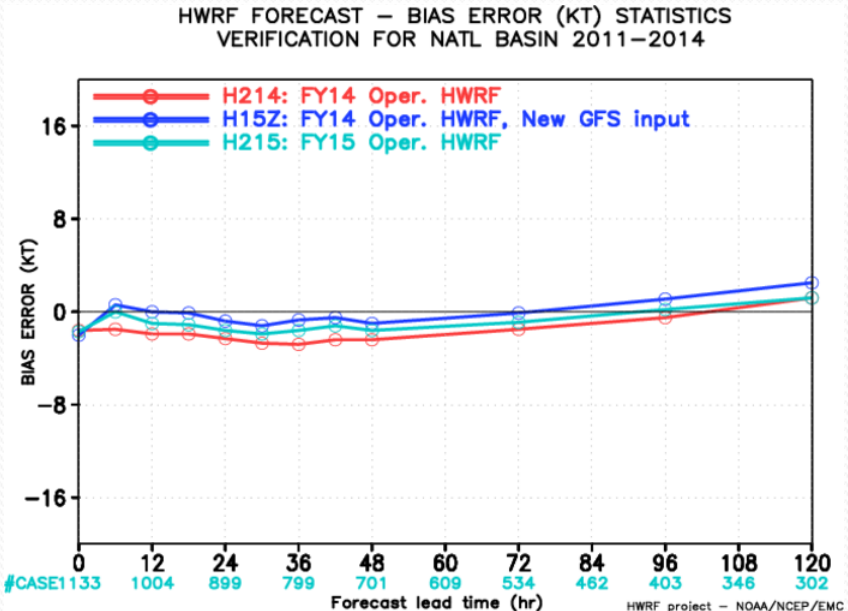




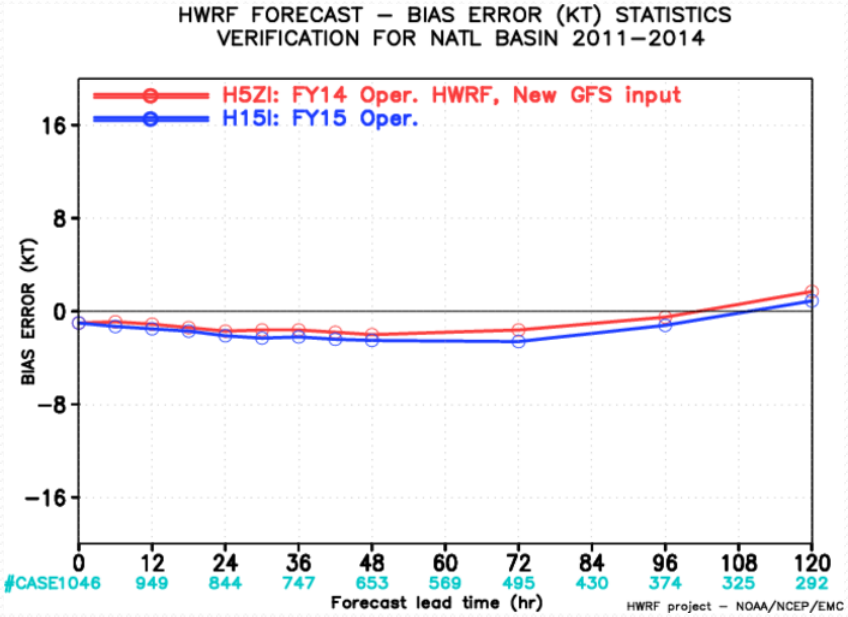
Impact of Physics, Resolution & New GFS, (H215 vs H15Z & H214)

NATL Intensity Bias Forecasts 2011-2014

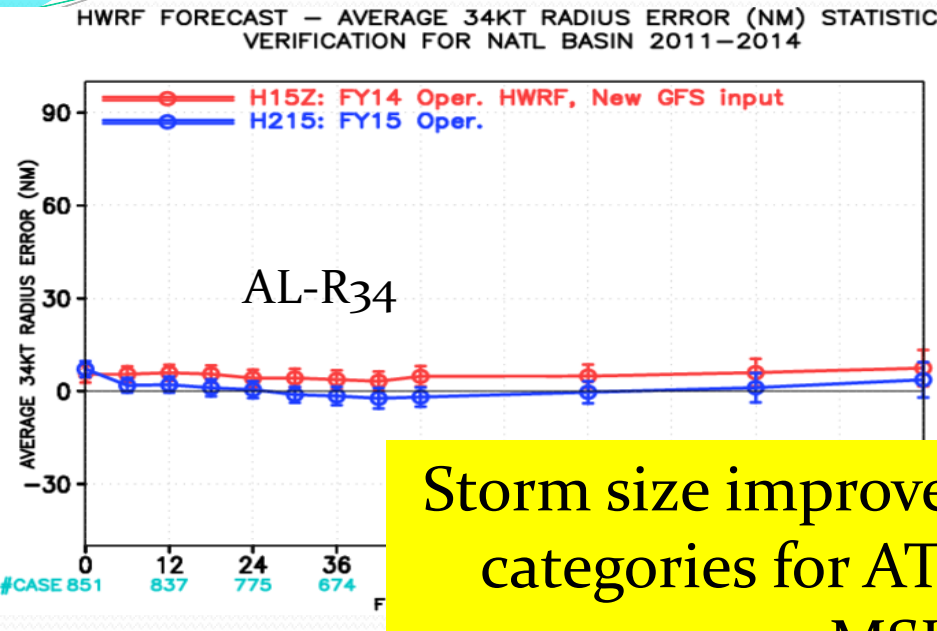


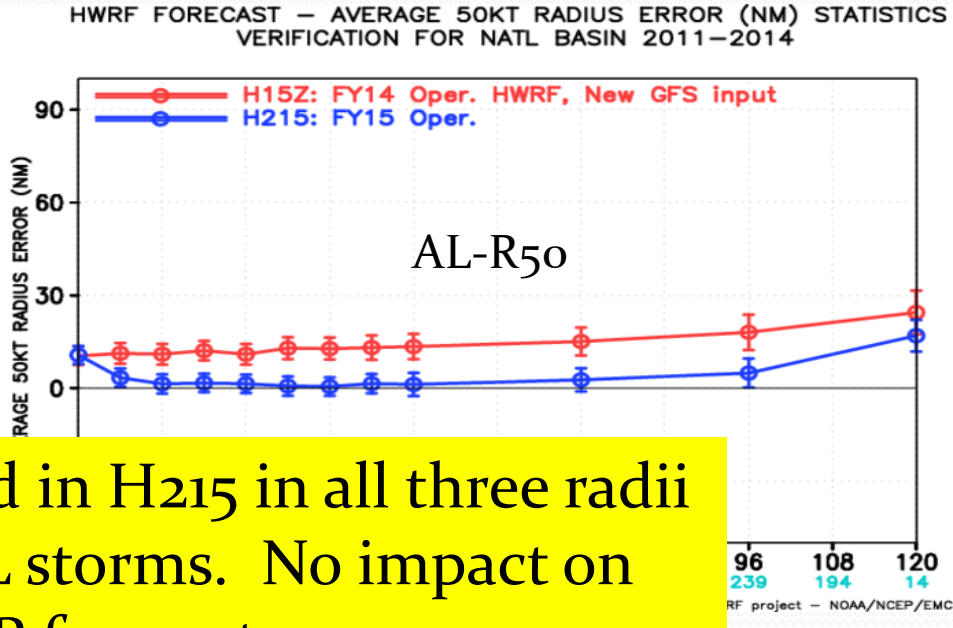


Intensity Forecast Bias stayed largely neutral, with slight improvements compared to H214/H15Z, trending towards positive bias at day-5.

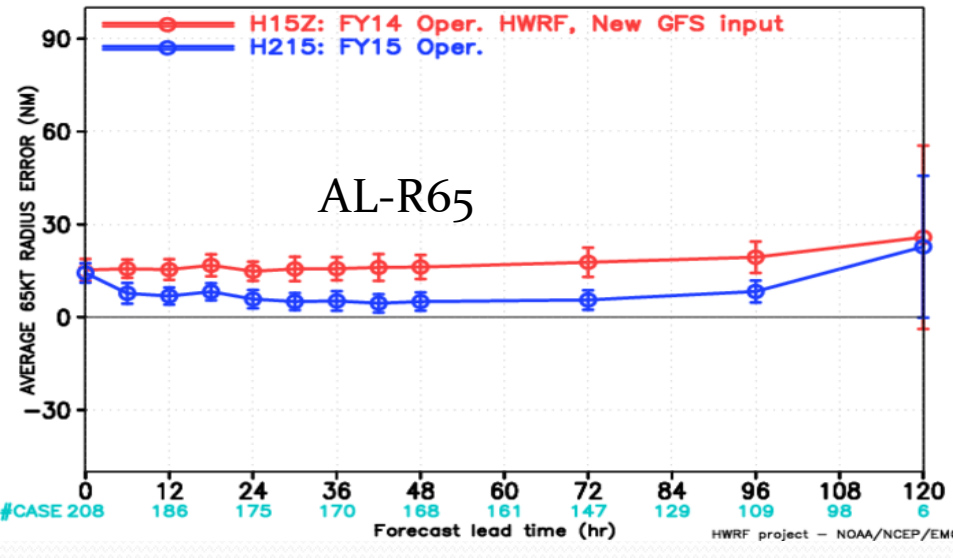


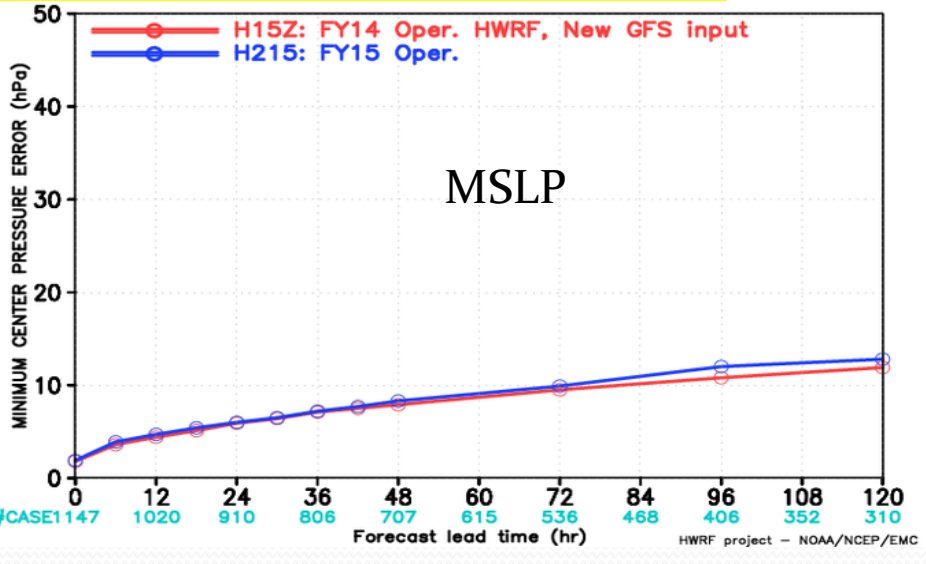
Storm Structure Verification for H215 vs H15Z, NATL 2011-2014



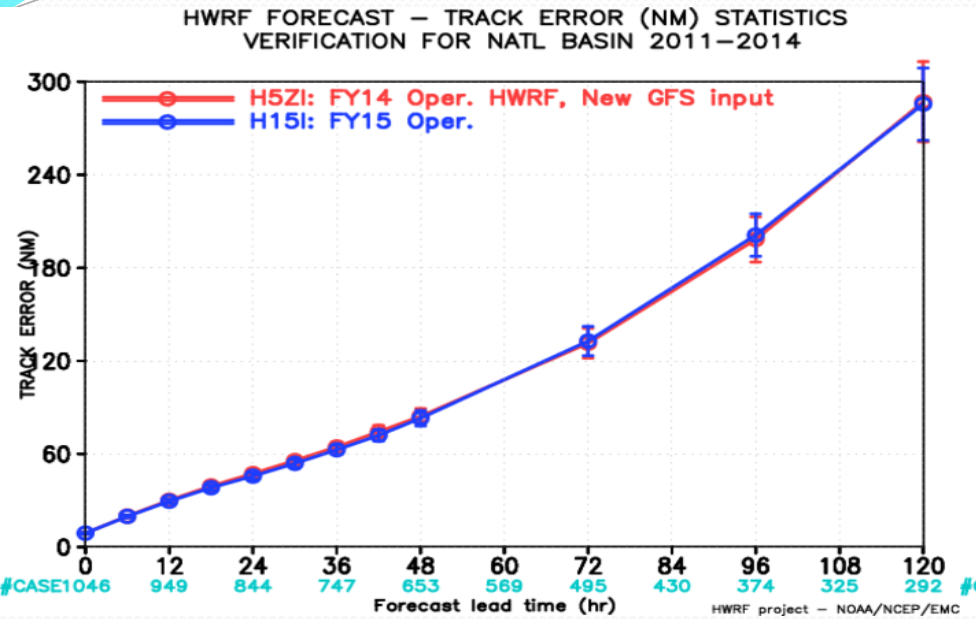


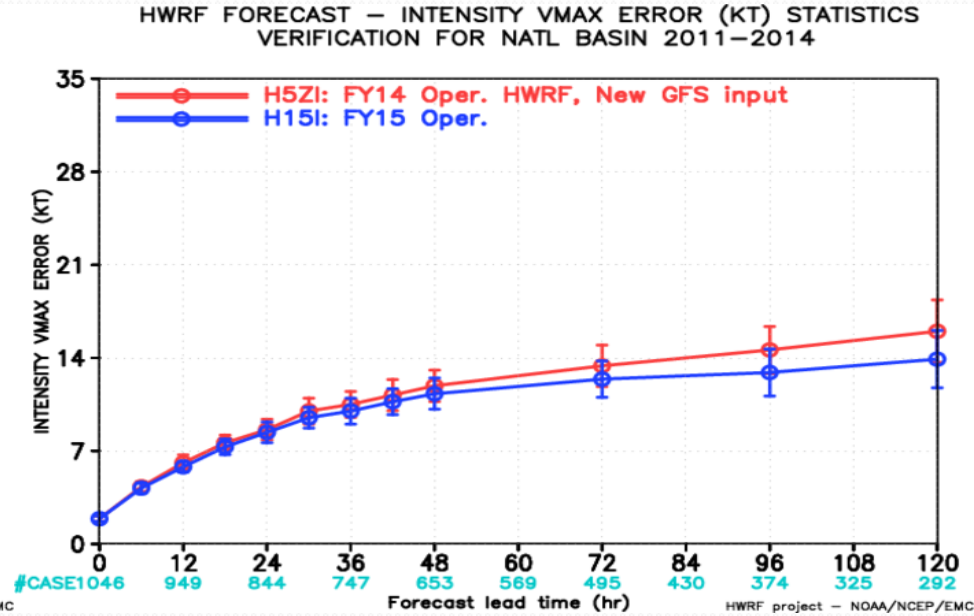
Storm size improved in H215 in all three radii categories for ATL storms. No impact on MSLP forecasts

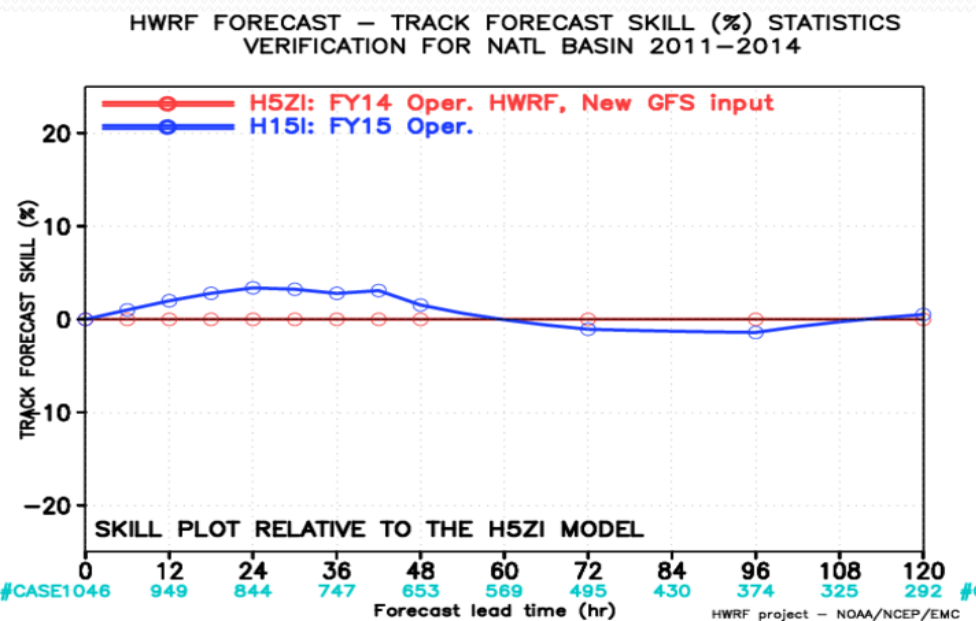


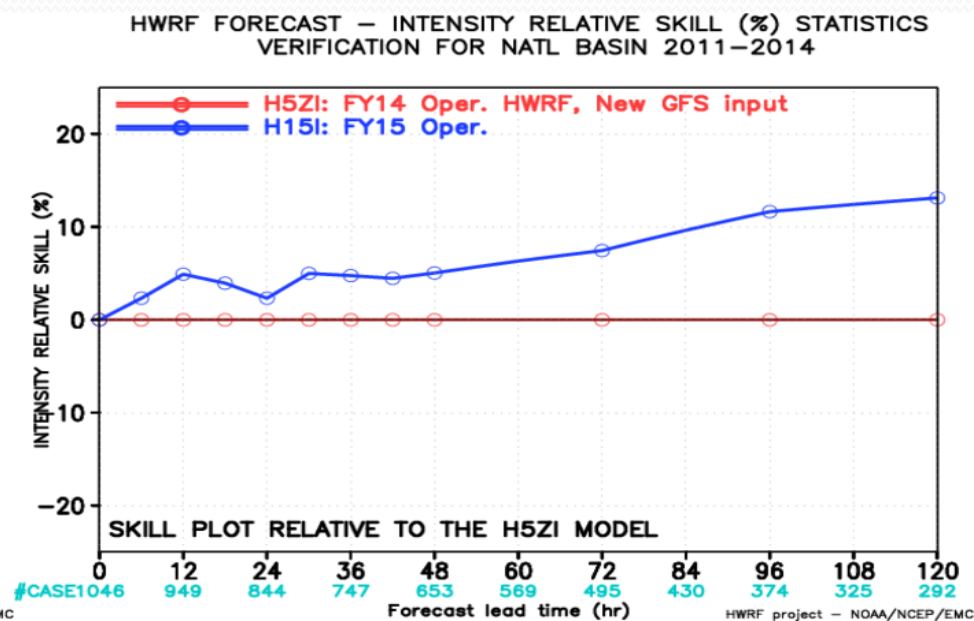


Verification of interpolated guidance, H15I vs. H5ZI, NATL 2011-2014

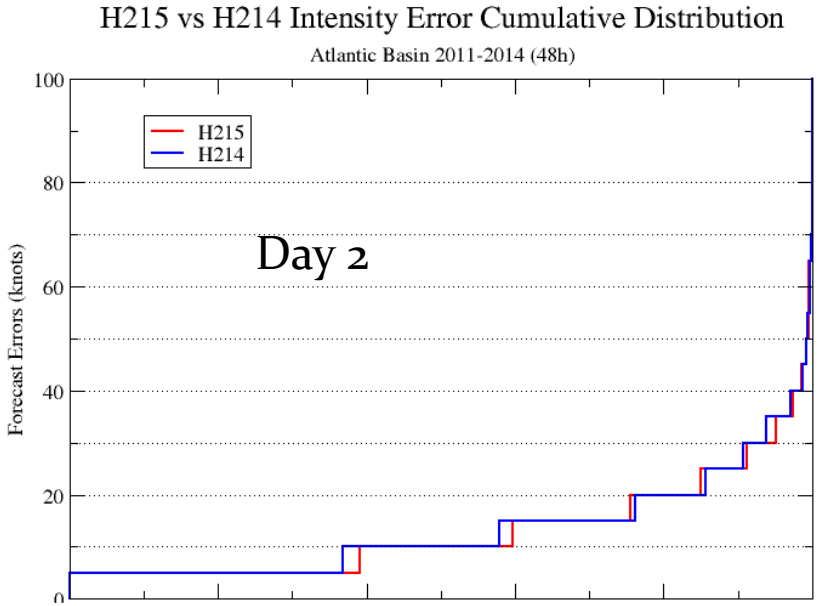


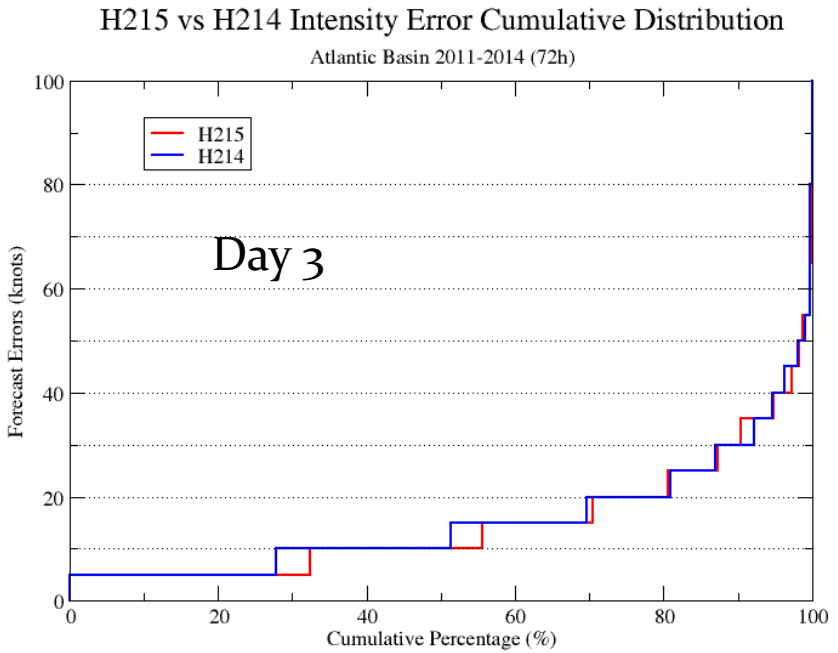


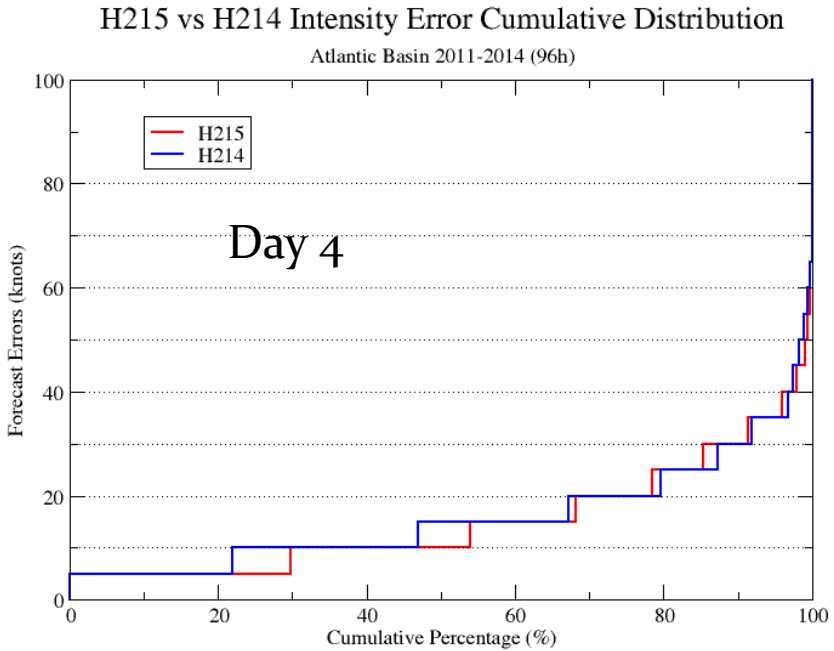


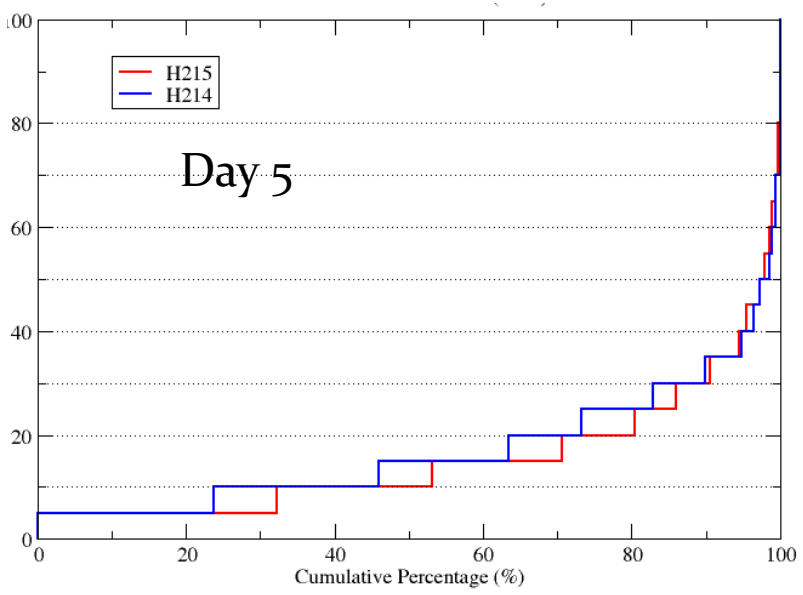


Improvement of Intensity Errors from H215, NATL 2011-2014

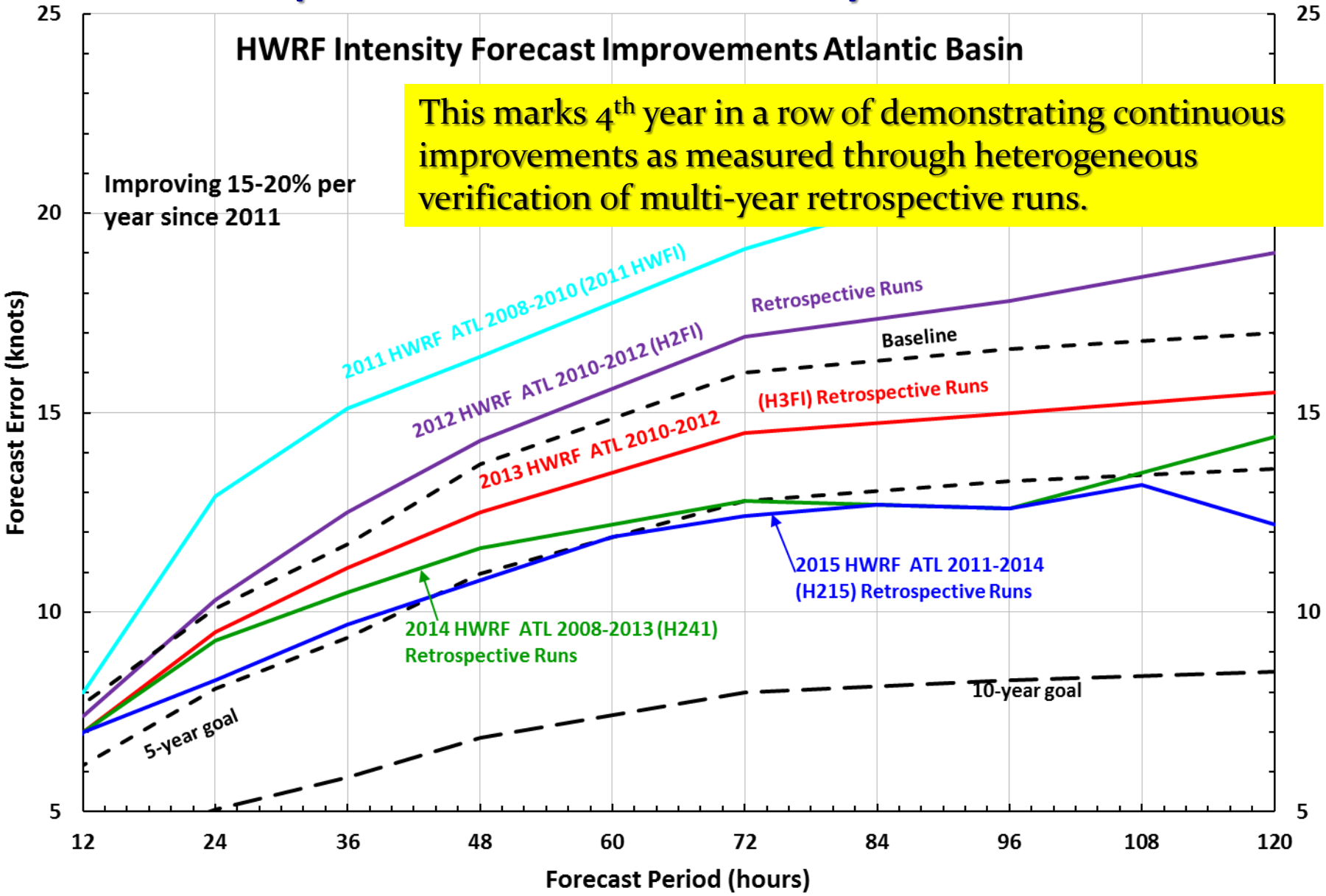






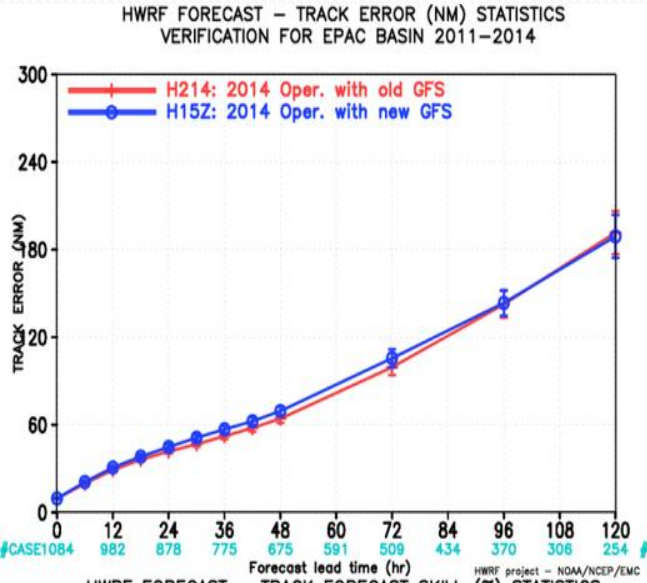


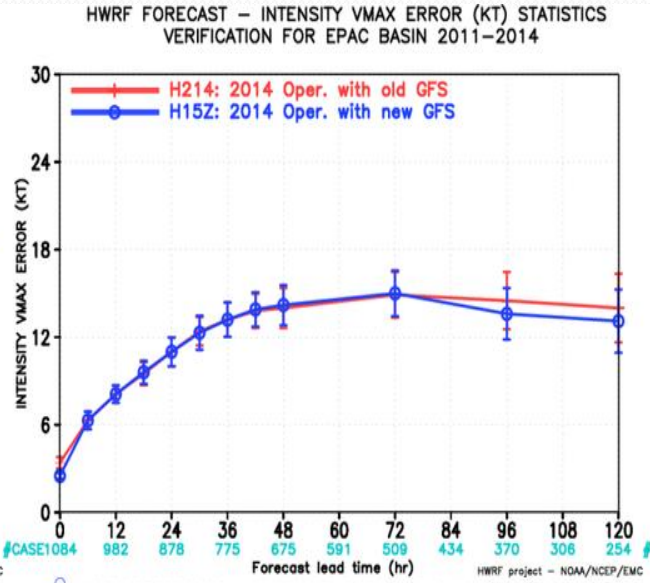
2015 HWRF: Continuing the trend of incremental but substantial improvements in NATL intensity forecasts

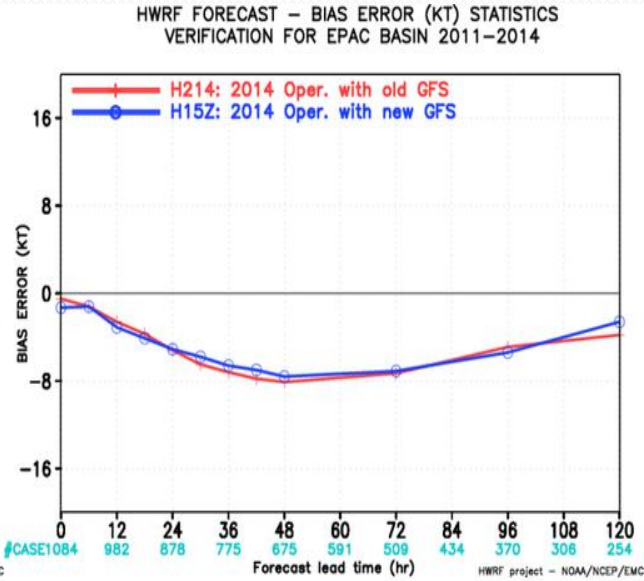


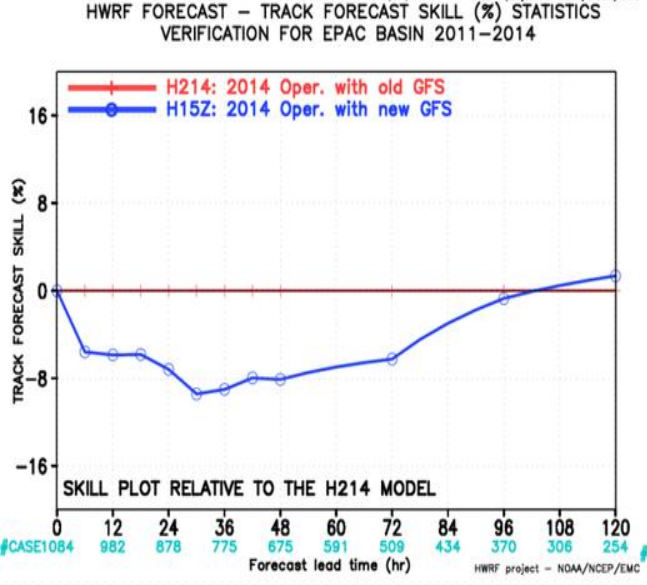
Verification for East-Pacific Storms (2011-2014)

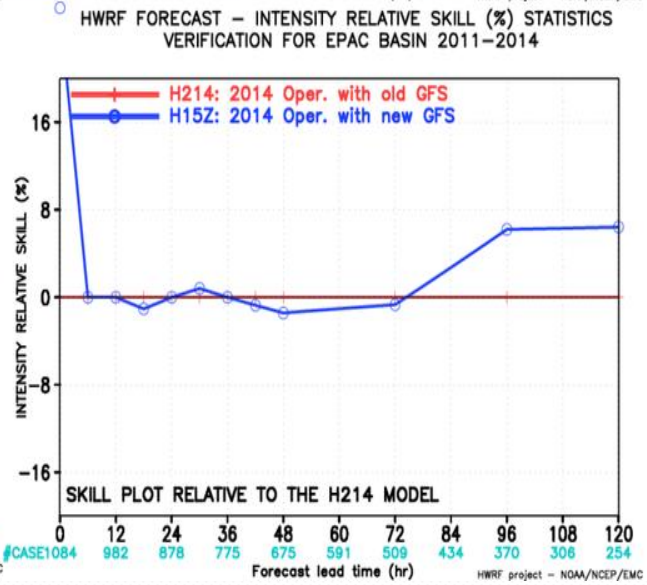
Impact of new GFS, EP, 2011-2014







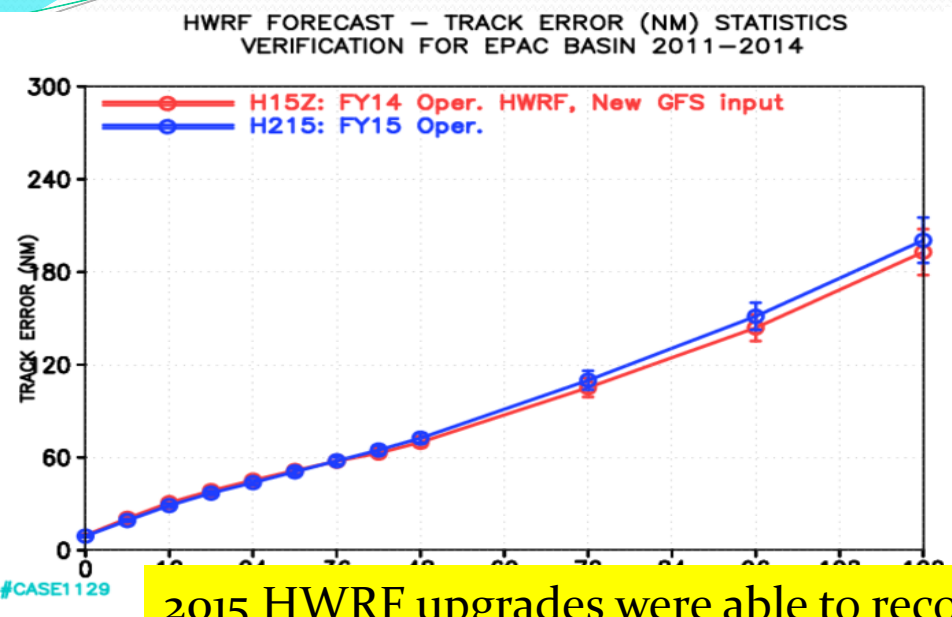


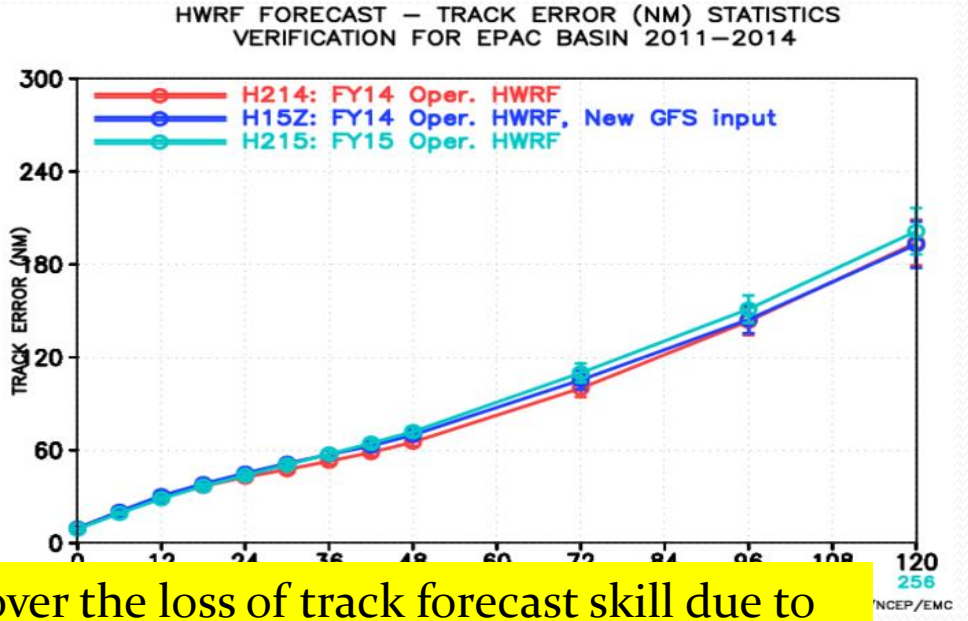


Track Forecast degraded from using new GFS upgrade. Some improvement in intensity forecasts at days 4/5, neutral intensity bias

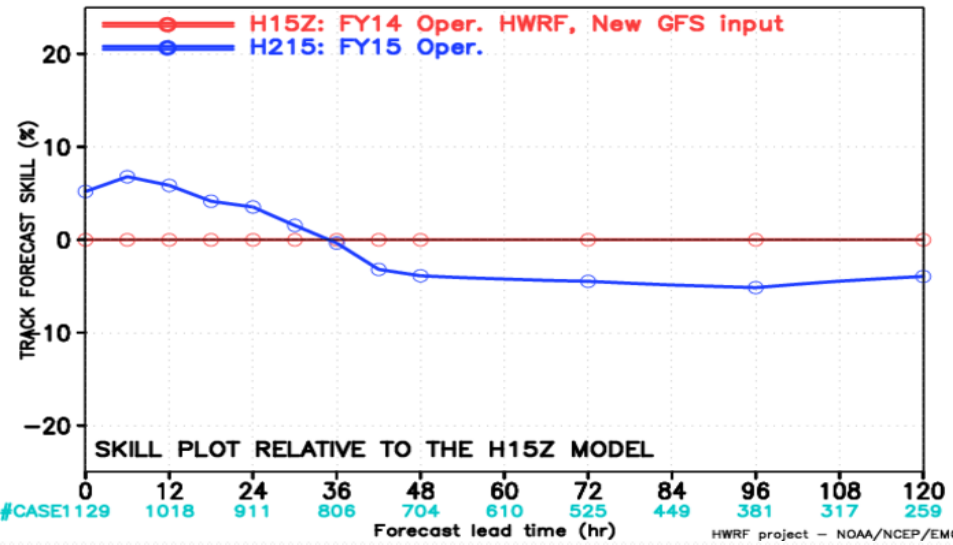
Impact of Physics, Resolution & New GFS, (H215 vs H15Z & H214)

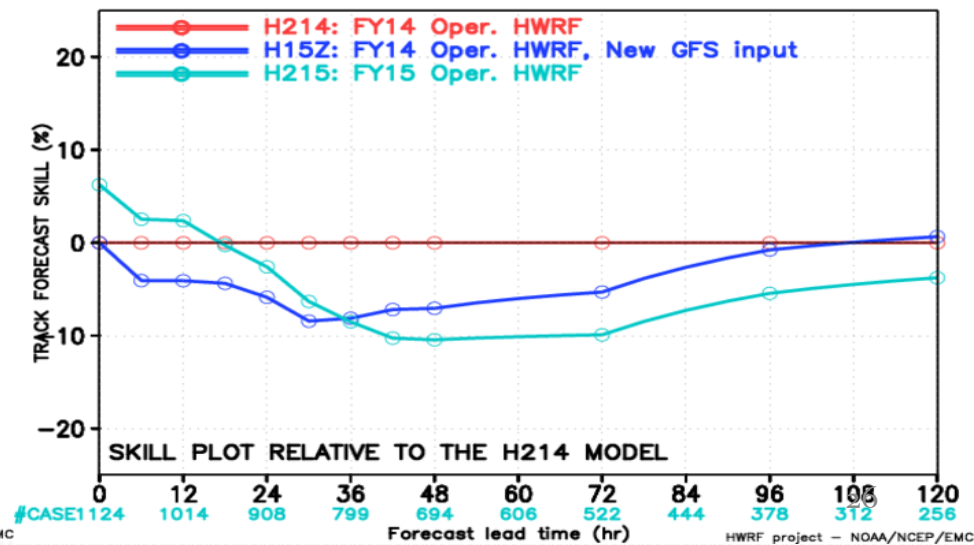
EP Track Forecasts 2011-2014





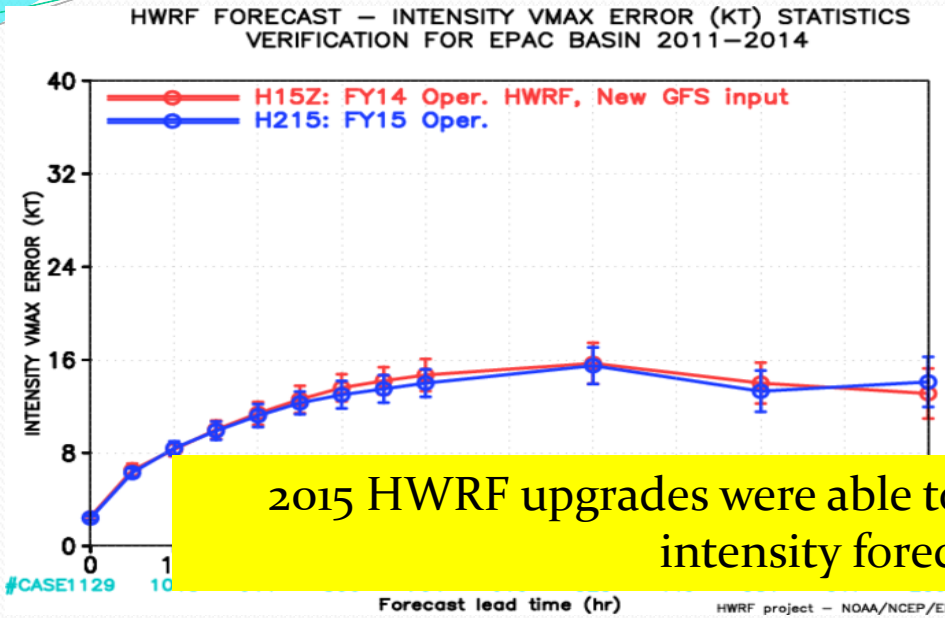
2015 HWRF upgrades were able to recover the loss of track forecast skill due to new GFS through 24 hrs, but remained largely negative 48 hrs and beyond

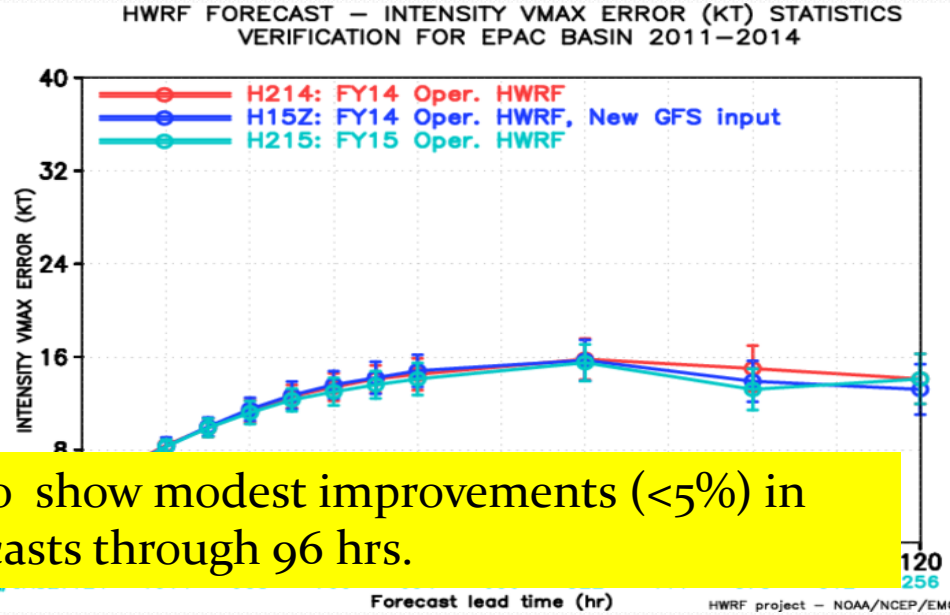




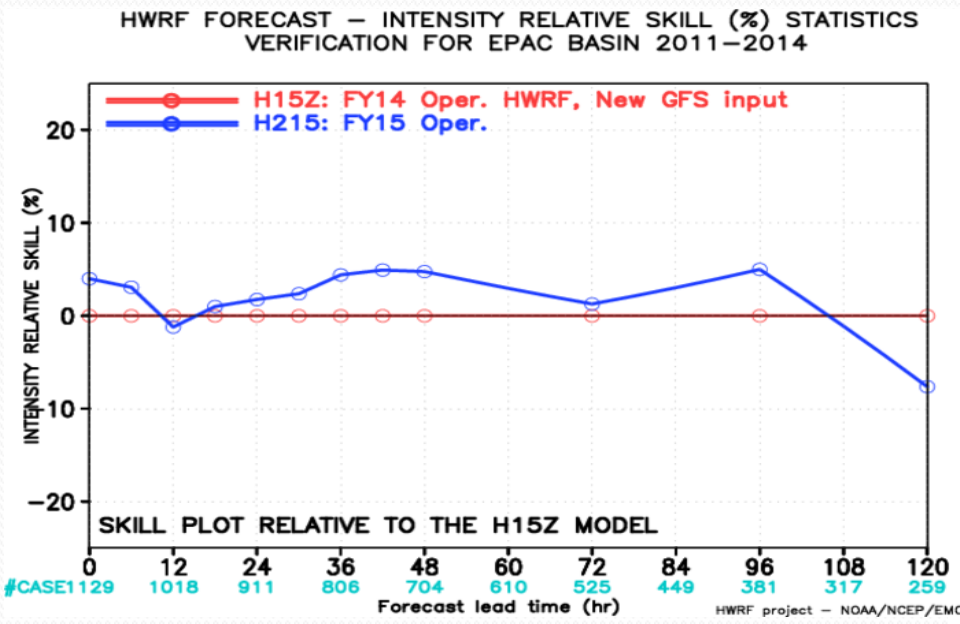
Impact of Physics, Resolution & New GFS, (H215 vs H15Z & H214)

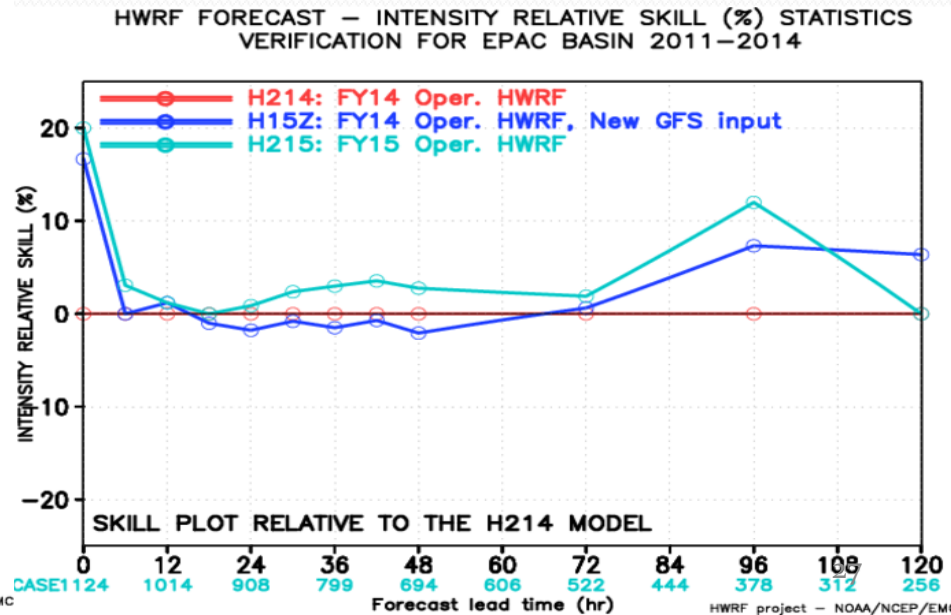
EP Intensity Forecasts 2011-2014





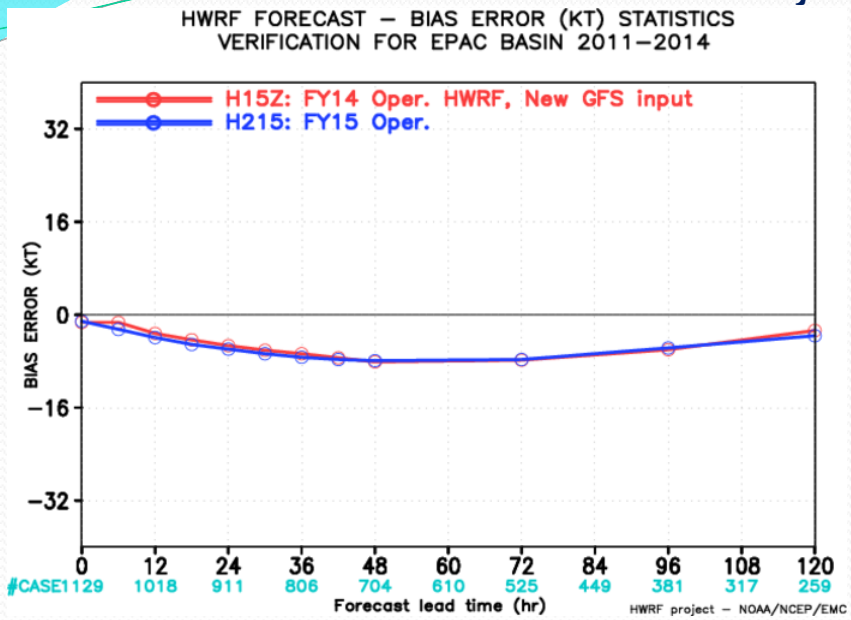
2015 HWRF upgrades were able to show modest improvements (<5%) in intensity forecasts through 96 hrs.

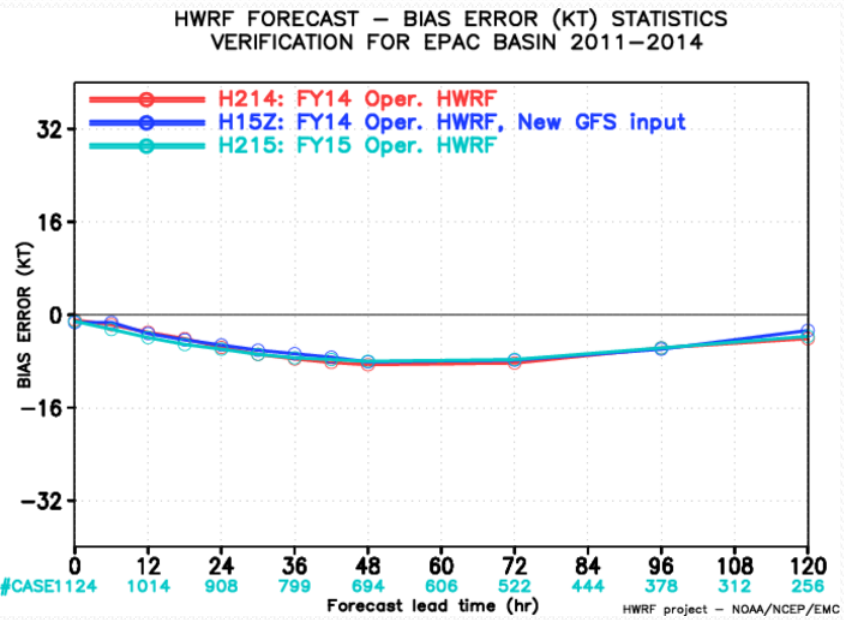




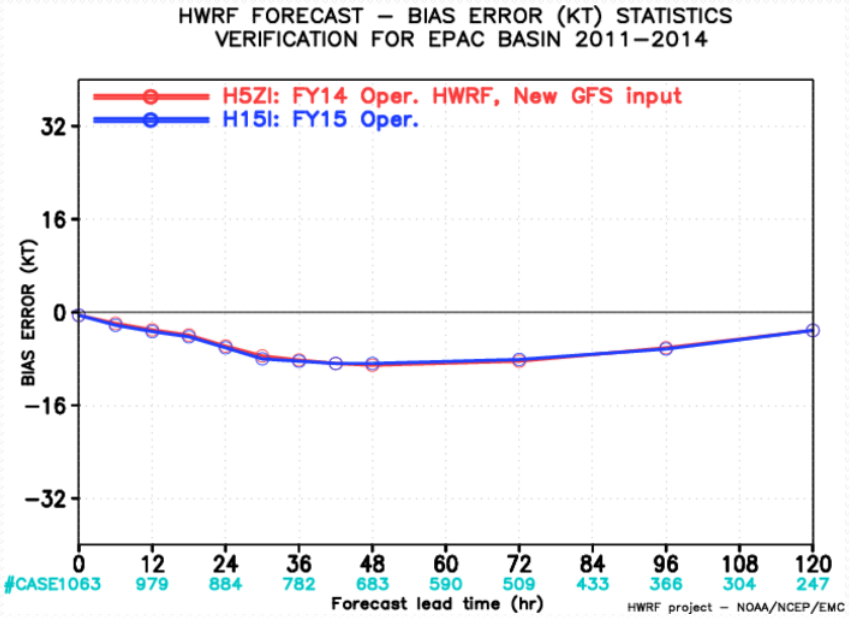
Impact of Physics, Resolution & New GFS, (H215 vs H15Z & H214)

EP Intensity Bias Forecasts 2011-2014

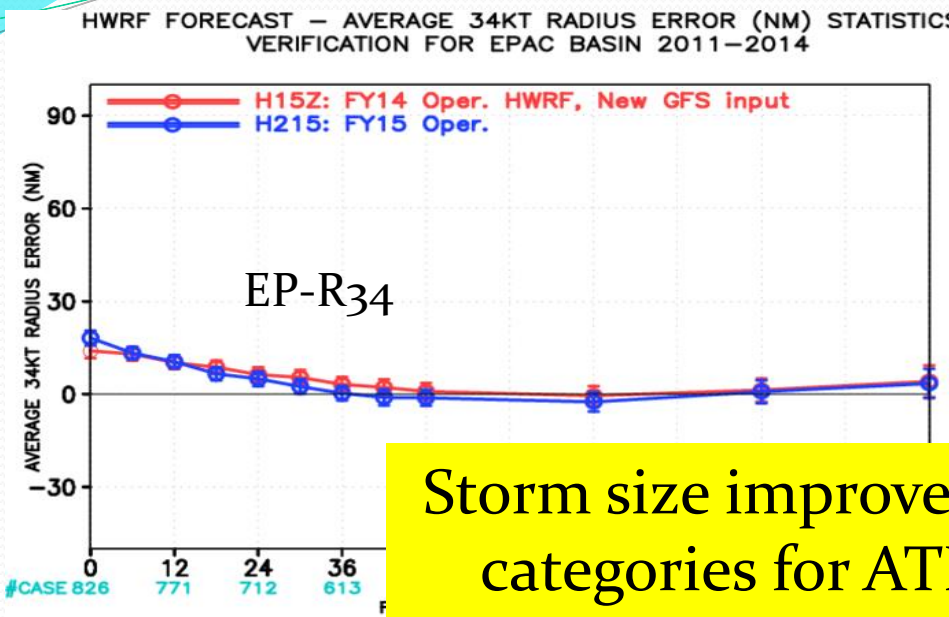


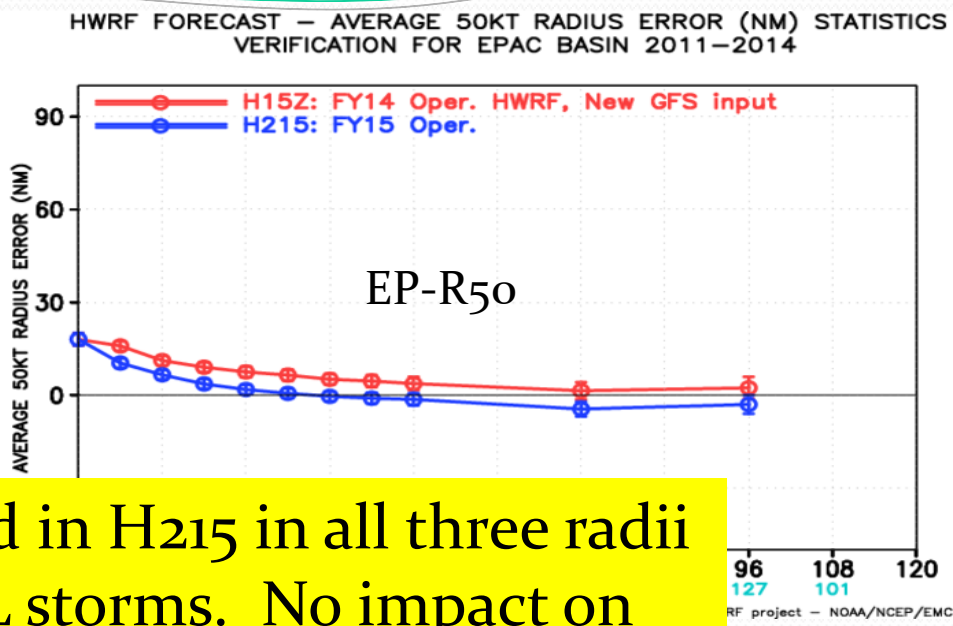


Intensity Forecast Bias remained the same (mostly negative) despite higher resolution and improved physics

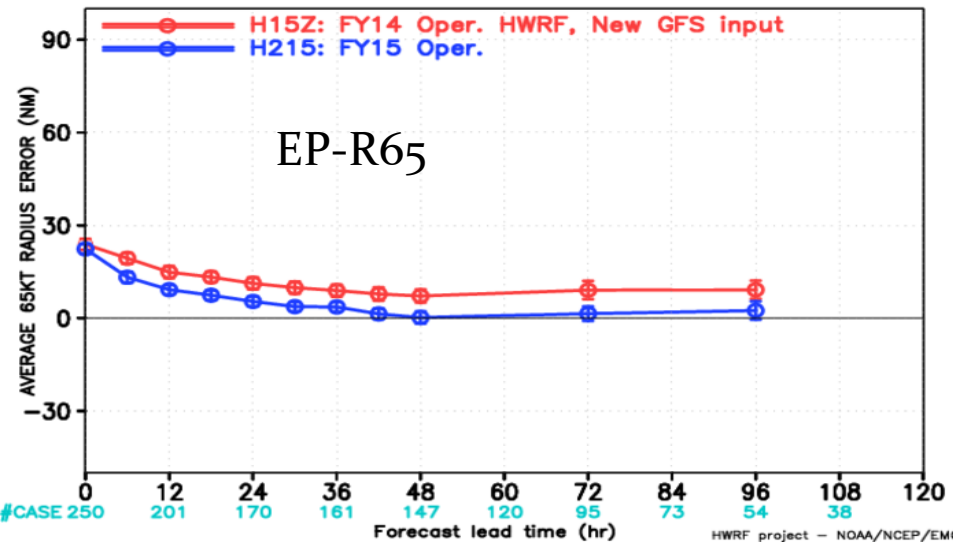


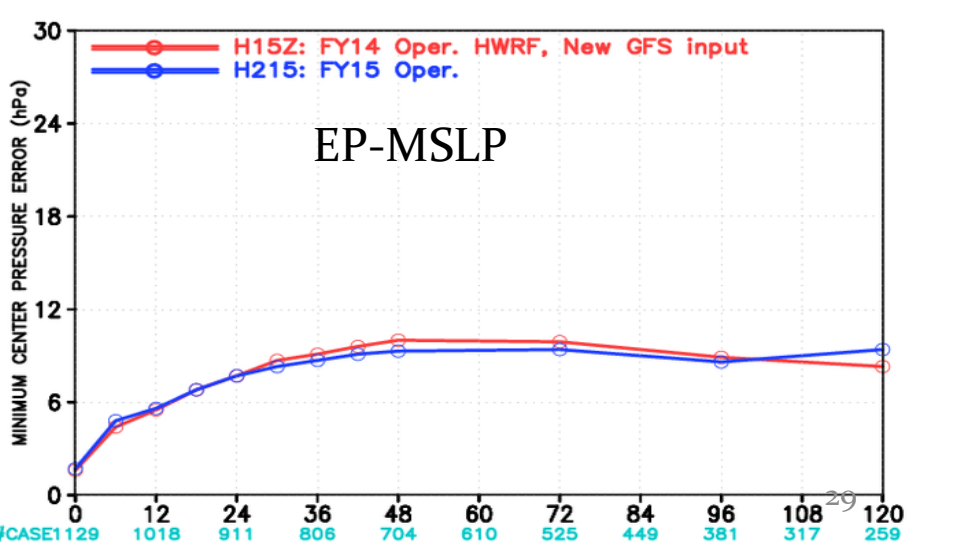
Storm Structure Verification for H215 vs H15Z, EP 2011-2014



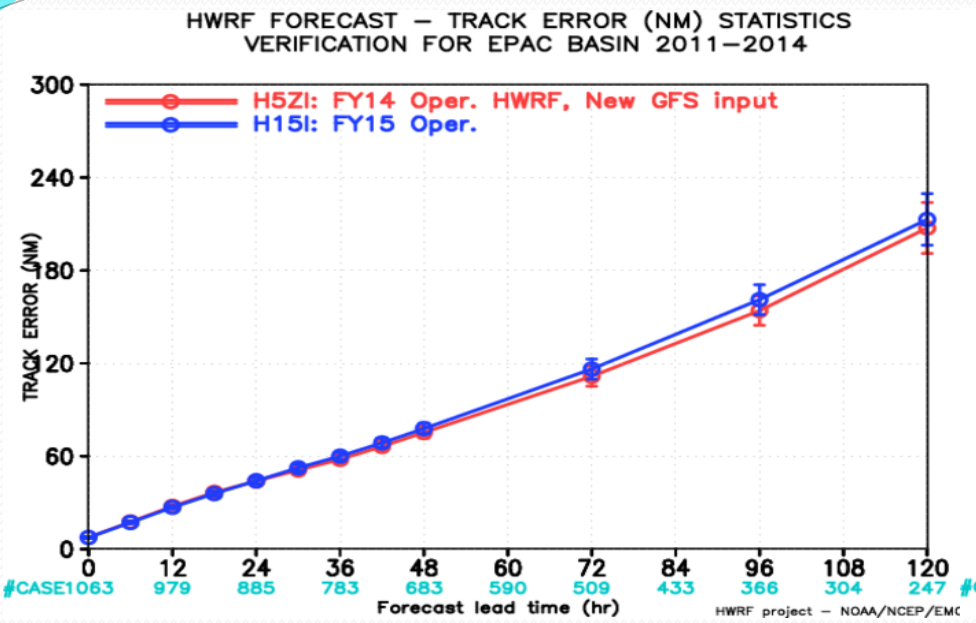


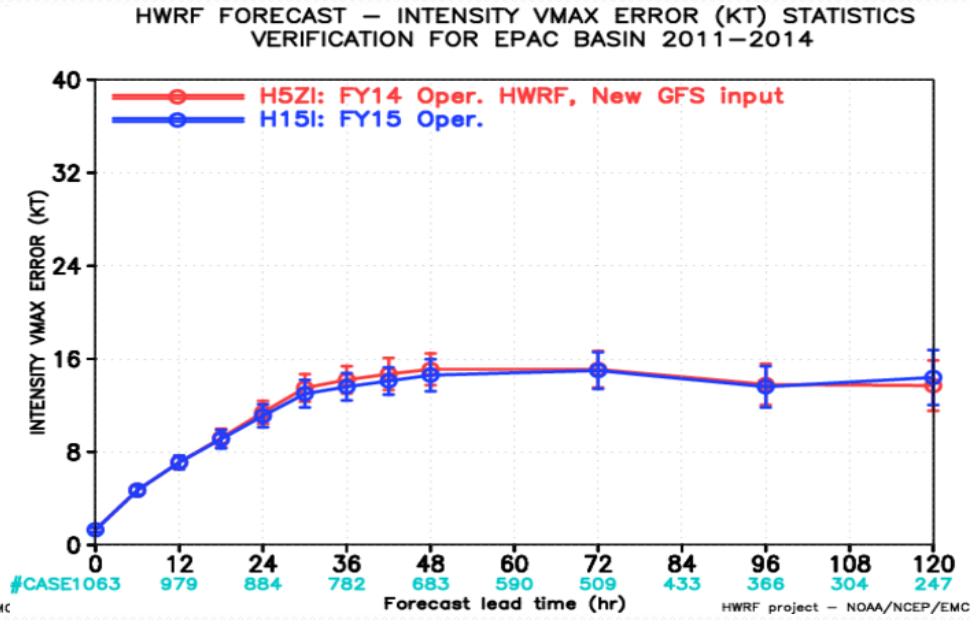
Storm size improved in H215 in all three radii categories for ATL storms. No impact on MSLP forecasts

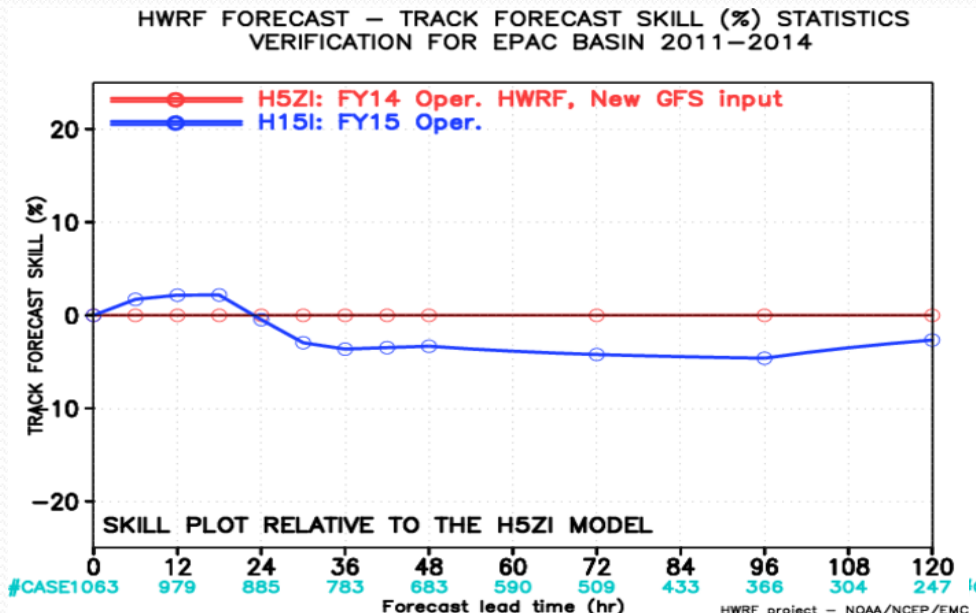


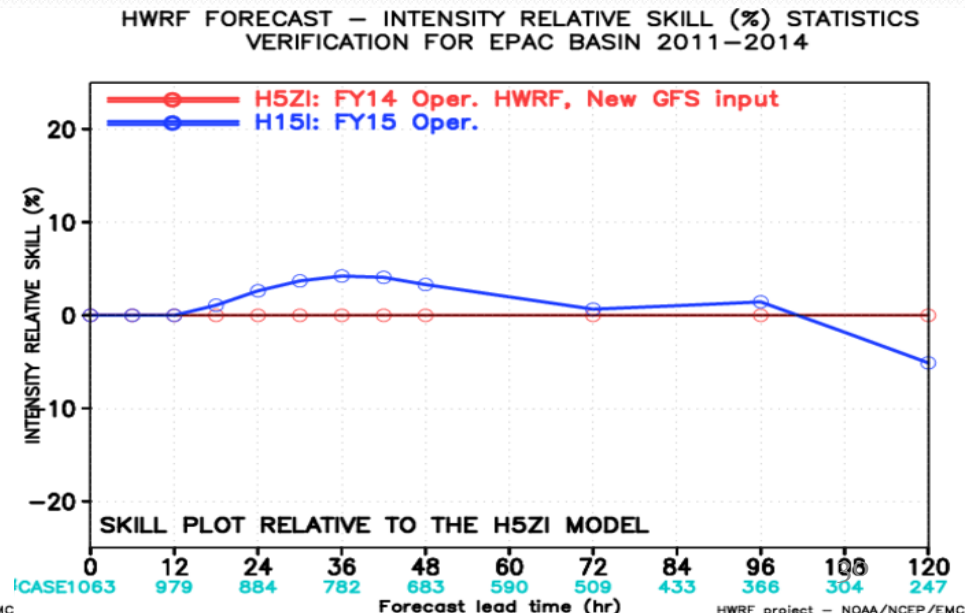


Verification of interpolated guidance, H15I vs. H5ZI, EP 2011-2014

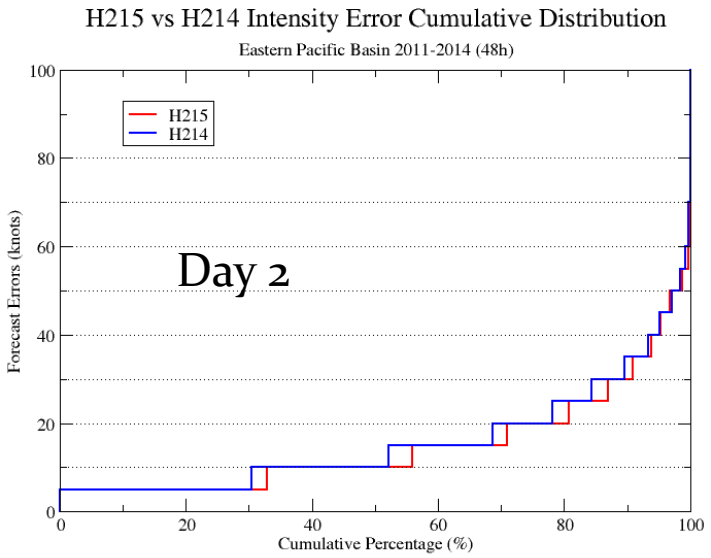


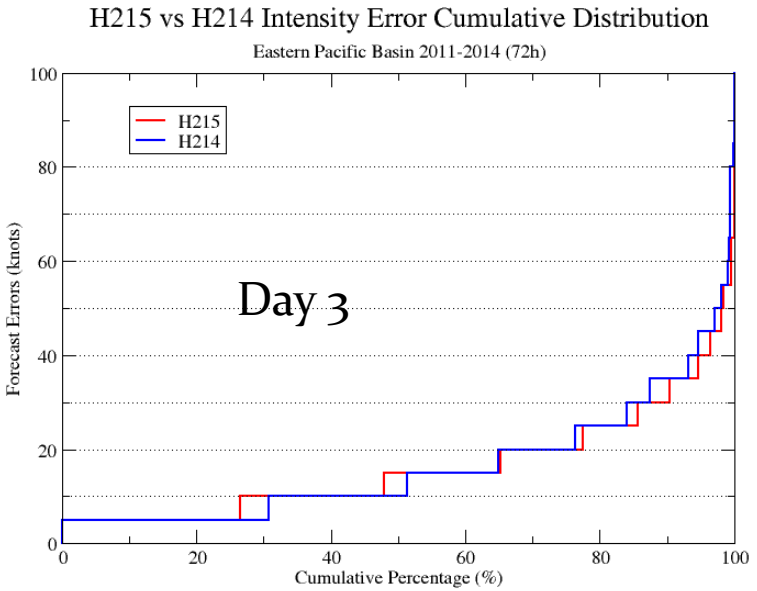


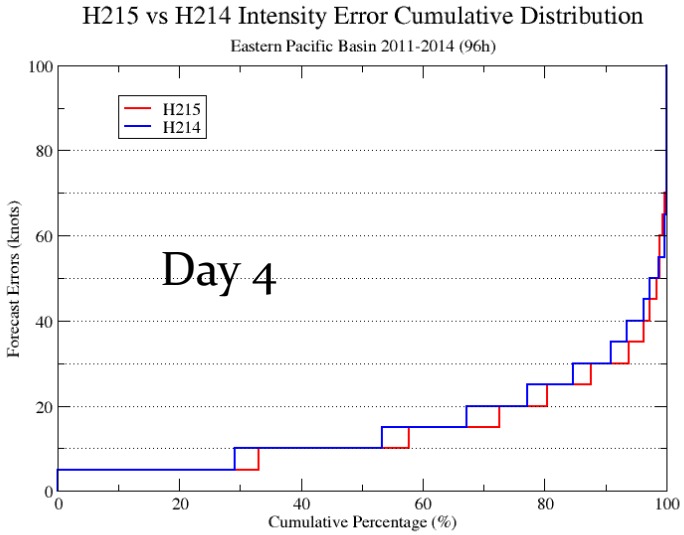


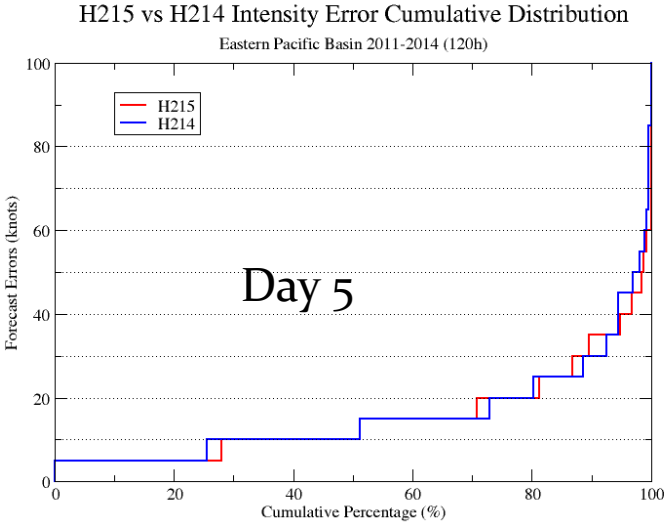


Improvement of Intensity Errors from H215, EP 2011-2014

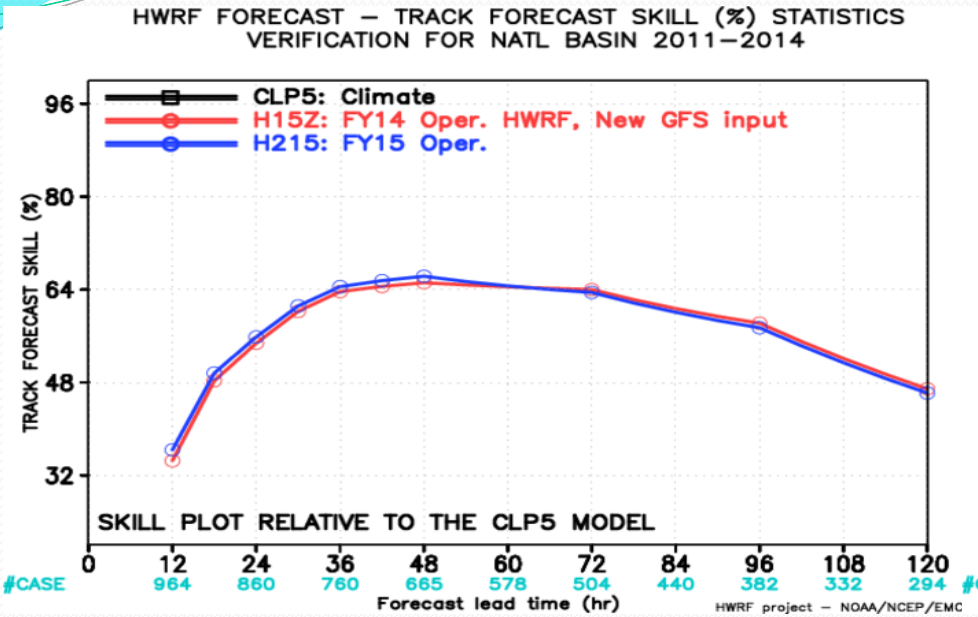


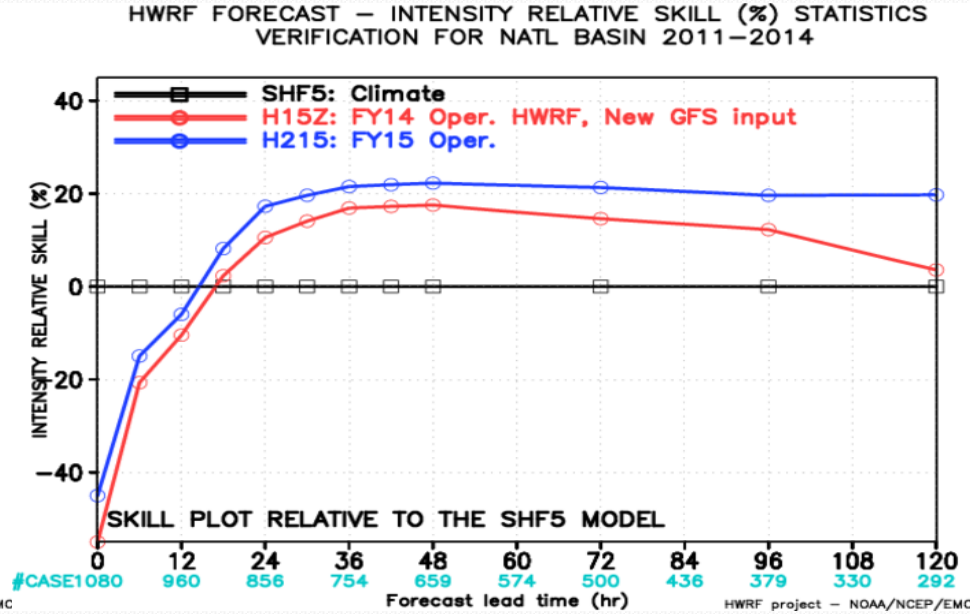


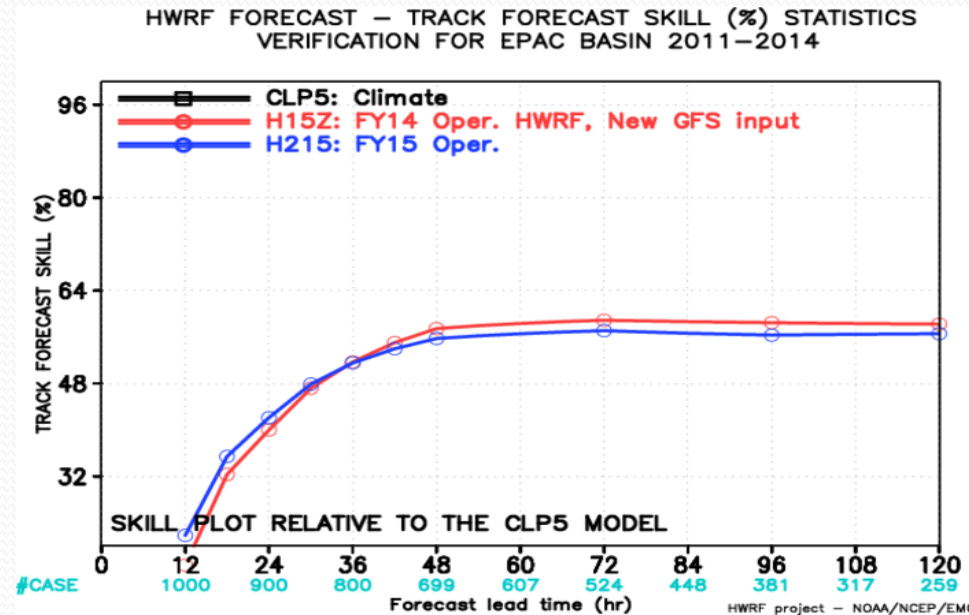


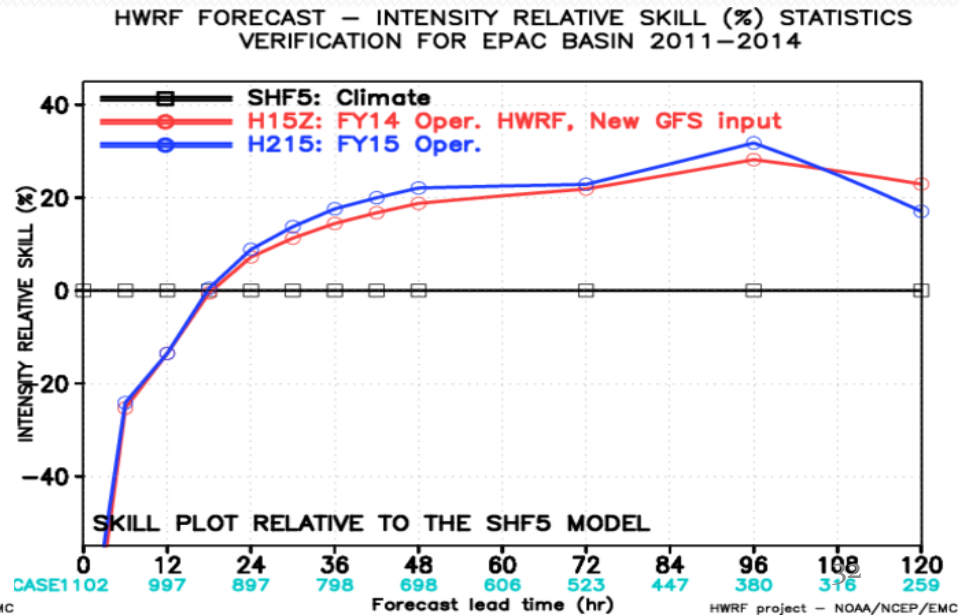


Verifications in Skill Space, H215 vs. H15Z, NATL/EP, 2011-2014

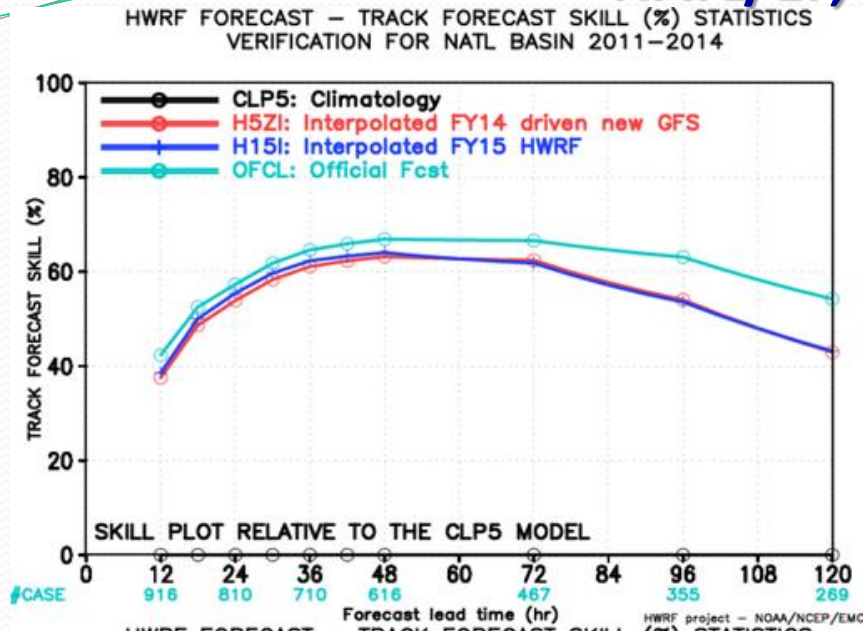


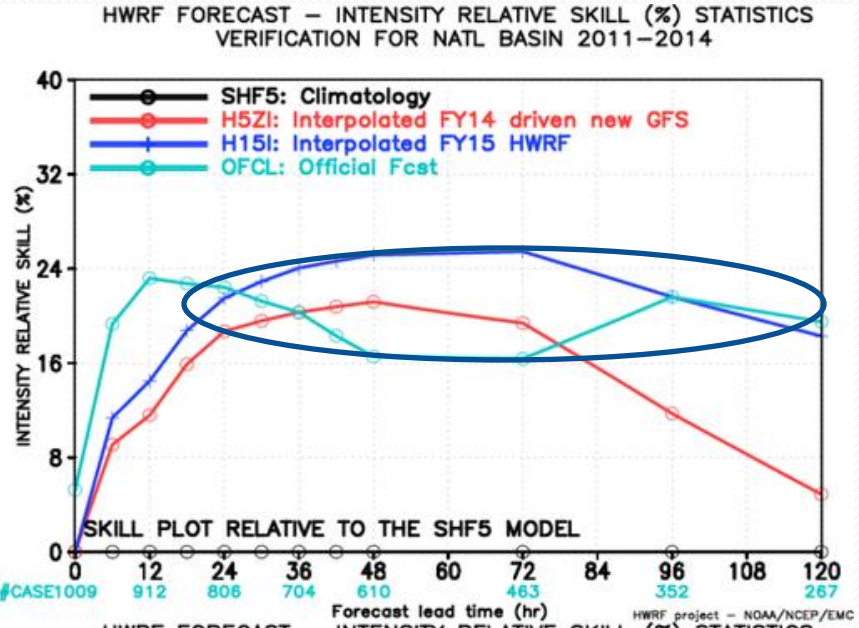


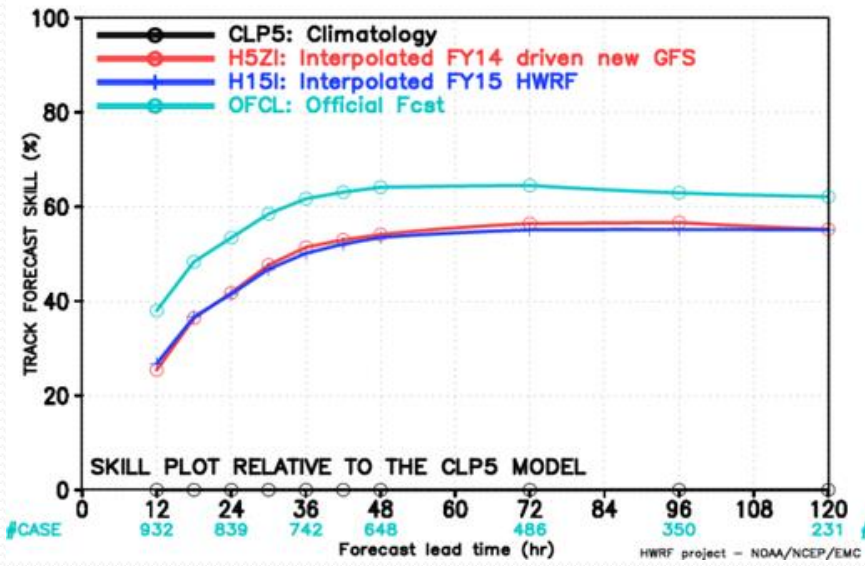


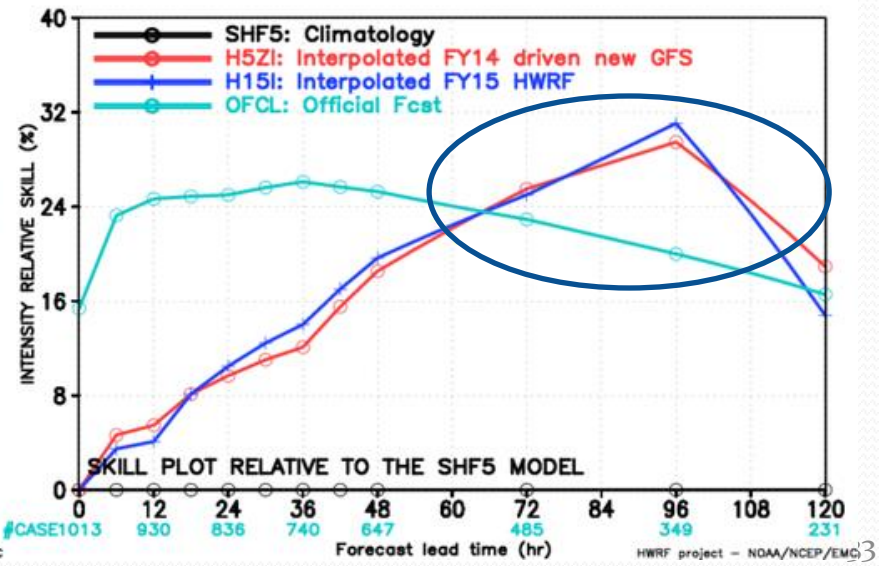


Early Model Verification in Skill Space, H215 vs. H15Z vs. OFCL, NATL/EP, 2011-2014

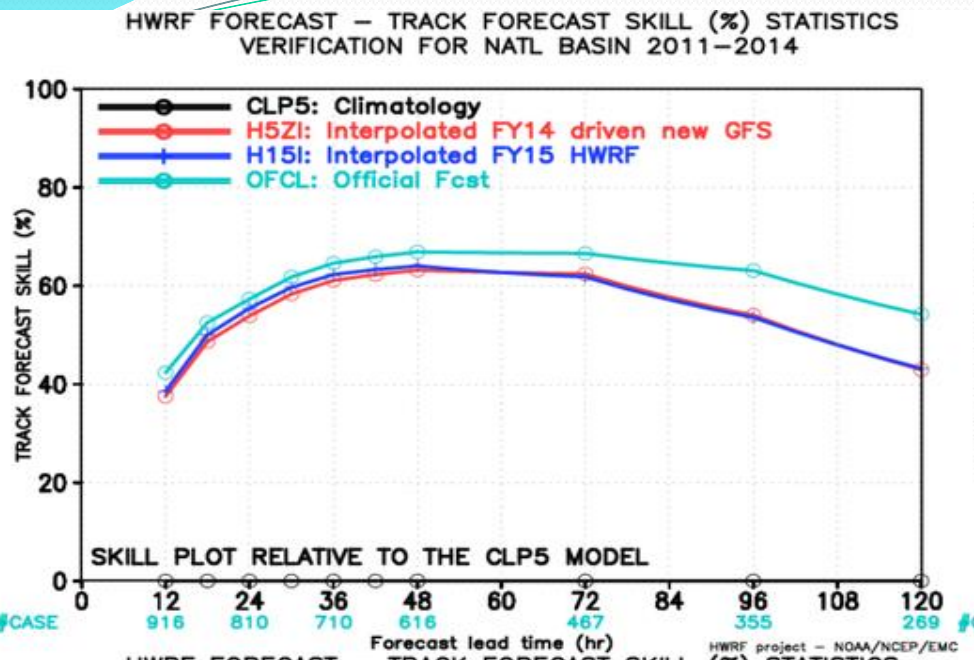


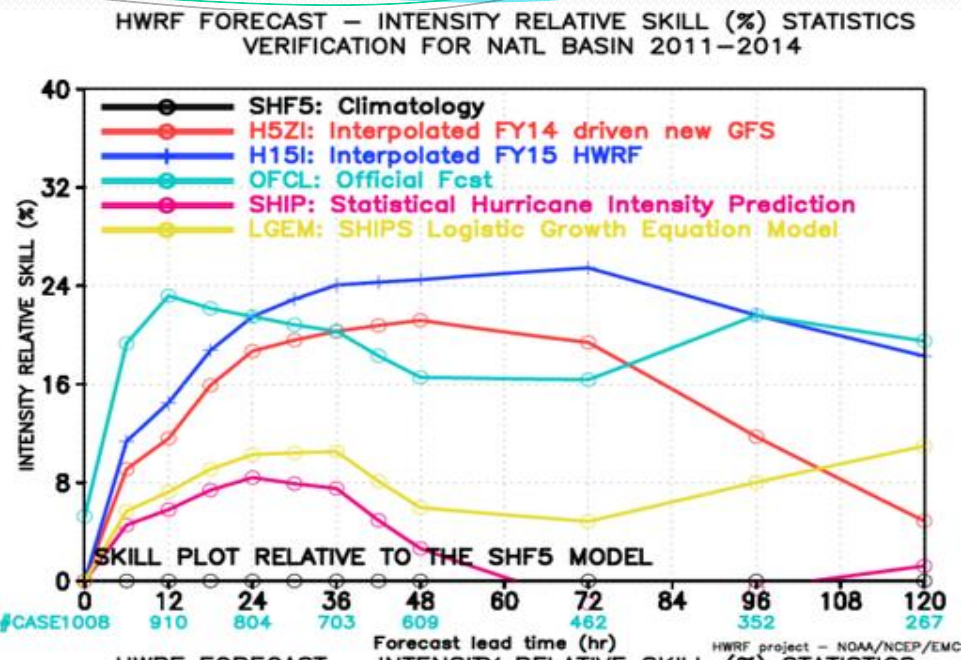


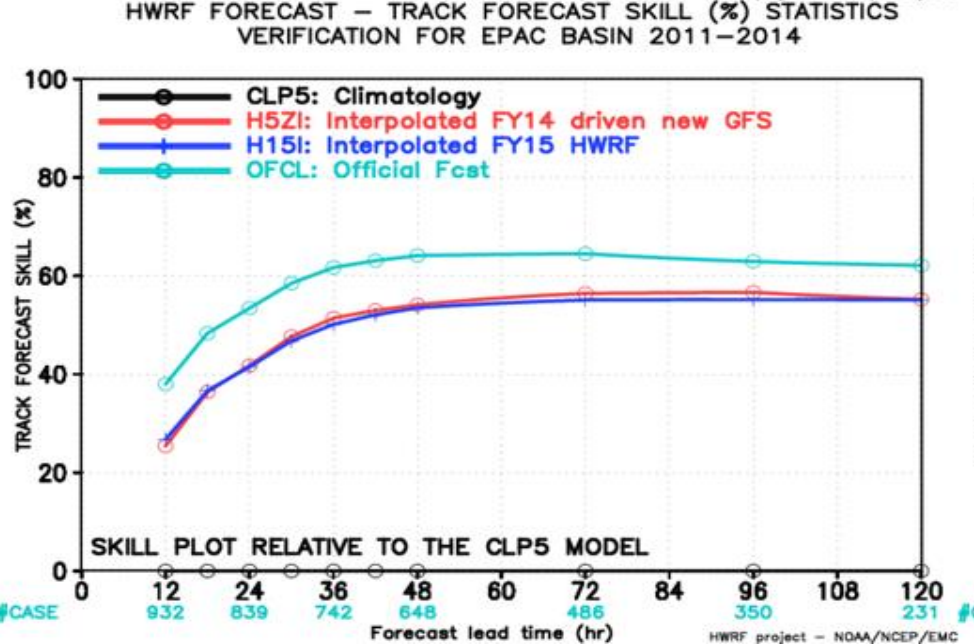


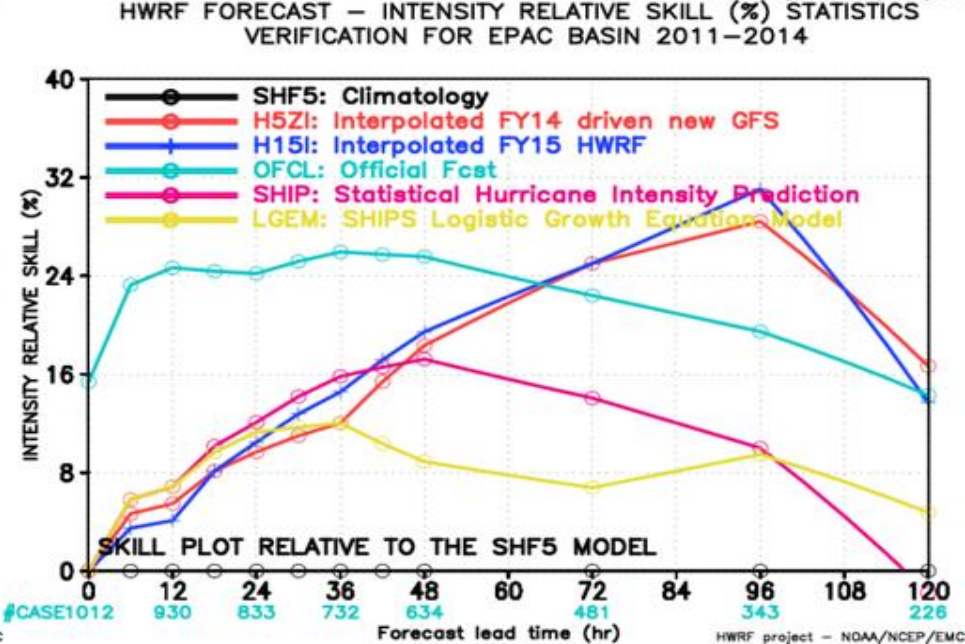


Early Model Verification in Skill Space, Comparison with statistical models

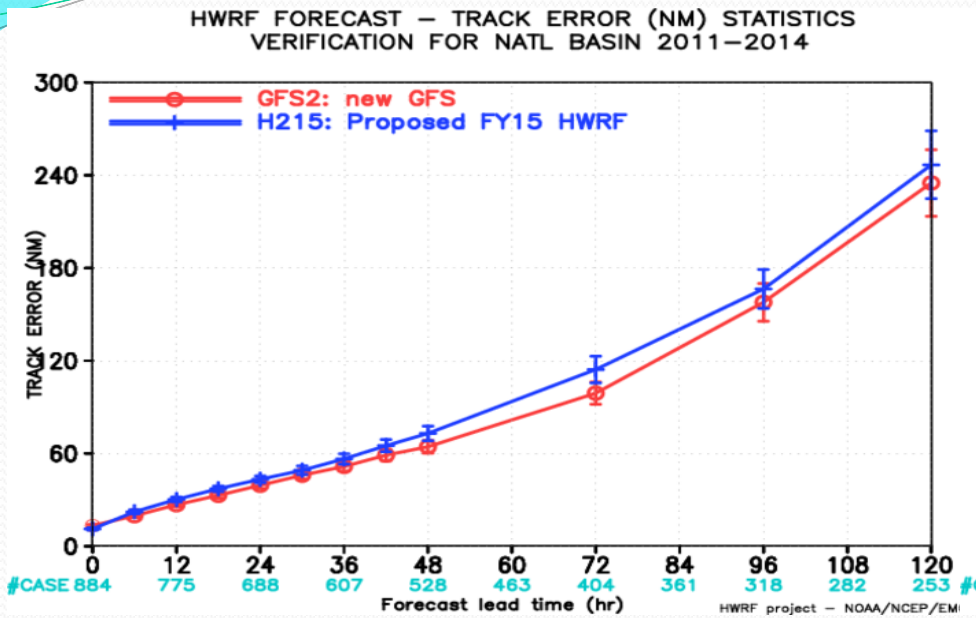


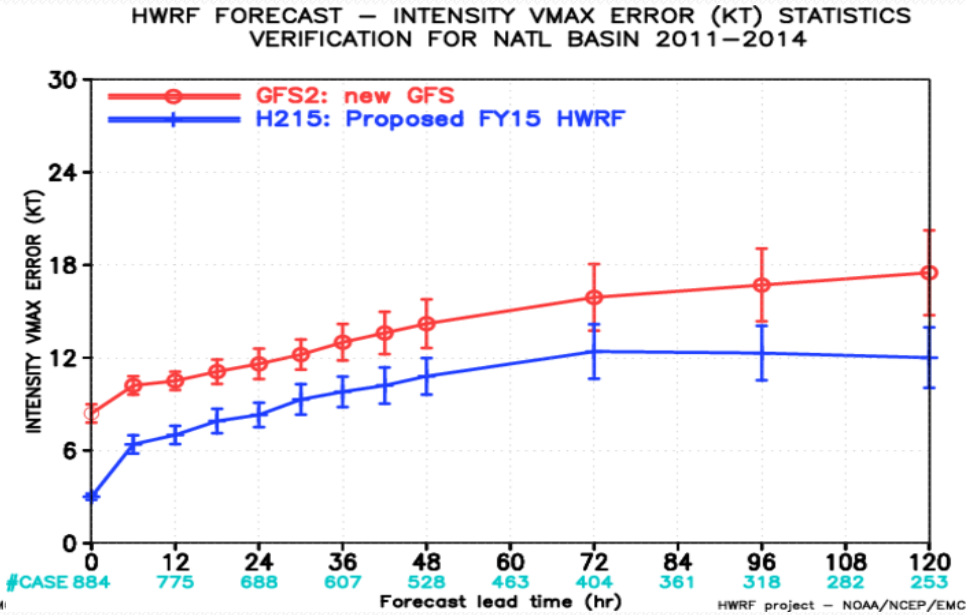


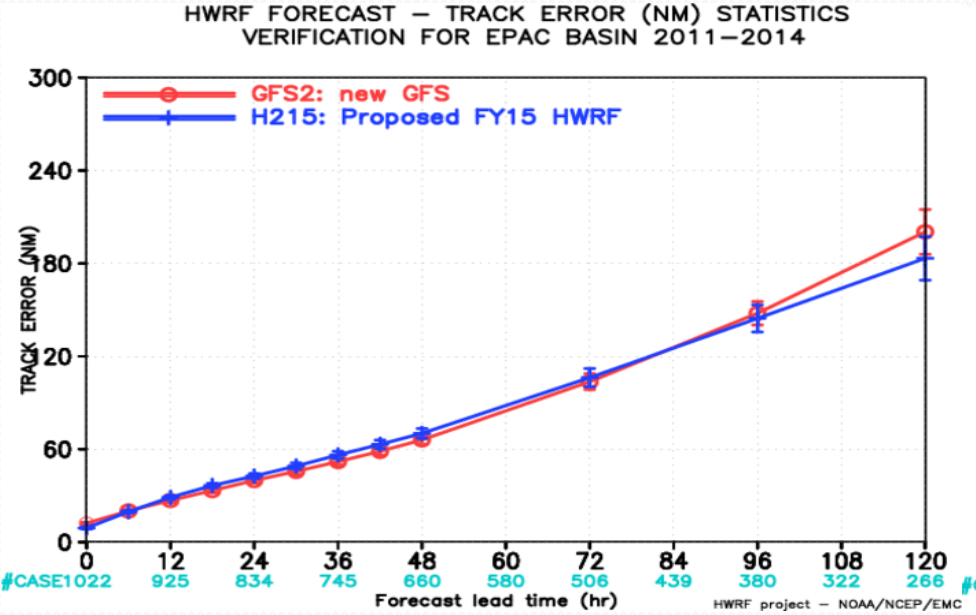


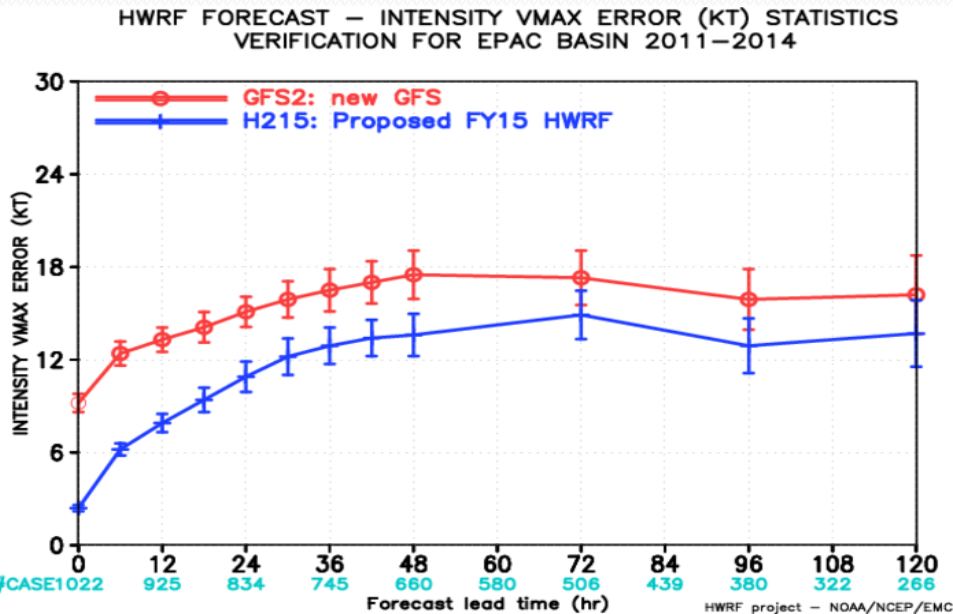


Verification Against new GFS, NATL/EP, 2011-2014









Summary

- Further enhancements suggested for 2015 operational HWRF include:
  - Increase the horizontal resolution from 27/9/3 to 18/6/2 km.
  - Upgrade and improve HWRF vortex initialization scheme
  - Upgrade DA with hybrid HWRF-based EnKF and GSI system.
  - Upgrade model physics to accommodate model resolution increase, including micro-physics process, radiation, surface physics, land surface and PBL.
- H215 retrospective evaluation of 2011-2014 hurricane seasons (1147 verifiable cycles in NATL, 1129 in EP) demonstrated improved forecasts compared to both FY14 operational HWRF (H214) and FY14 driven by new GFS (H15Z), except for the track forecasts in the Eastern Pacific;
- Results from H215 for the Atlantic basin suggested additional 10-15% improvement possible from the newly upgraded model compared to H15Z, about 5-10% improvement compared to H214.
- Results from H215 for the Eastern Pacific basin suggested about 5% more track forecast errors compared to H15Z, however, H215 track forecasts are still comparable or better than the new GFS track forecasts. A modest (~5%) improvement in intensity forecasts is shown possible from 2015 HWRF upgrades .

Summary

- Evaluation metrics in the skill space confirmed the positive improvements from H215 compared to H15Z in both basins for intensity forecasts, and in the Atlantic for track forecasts.
- High-resolution ensemble based TDR DA paves way for the next generation vortex scale DA efforts supported by HFIP, while bringing immediate benefits in the operations.
- Centralized HWRF Development Process for both research and operations with community involvement is critical for making further enhancements.
- Full credits to the entire HWRF team for another successful execution of pre-implementation T&E for implementing improved HWRF model in operations.
- Looking forward to realize these improvements in real-time during the upcoming hurricane season, and help enhance the skills of official forecasts
- Seek more direct engagement of HFIP supported researchers for active participation in model evaluation, enhancements and future R2O.

NHC Evaluation and Recommendations

The National Hurricane Center (NHC) endorses your proposed implementation of the HWRF model for 2015. Included in this implementation are an increase in inner mesh horizontal resolution from 3 km to 2 km, a number of physics upgrades, and an improved initialization. Retrospective runs of this model for a very large number (on the order of 2000) of cases for the Atlantic and eastern North Pacific for 2011 through 2014 did yield some mixed results. ***When comparing the proposed implementation with the alternative (2014 HWRF driven by the 2015 GFS), there was a positive impact on intensity forecasts at both short and long ranges for the Atlantic and short-range intensity forecast improvements, with neutral impact at long ranges, for the east Pacific. There were overall improvements in short-range track prediction, with slight degradations at longer ranges, in the Atlantic . There were slight improvements in short-range track forecasts, with some degradation at the longer ranges, in the east Pacific.*** It should be noted that at least part of the track forecast degradations are resulting from the 2015 implementation of the GFS, as revealed by the reruns of the 2014 HWRF using the 2015 GFS. This HWRF implementation at least partly offsets the latter degradations, and ***given the positive benefits for TC intensity prediction, it is approved by the NHC.***

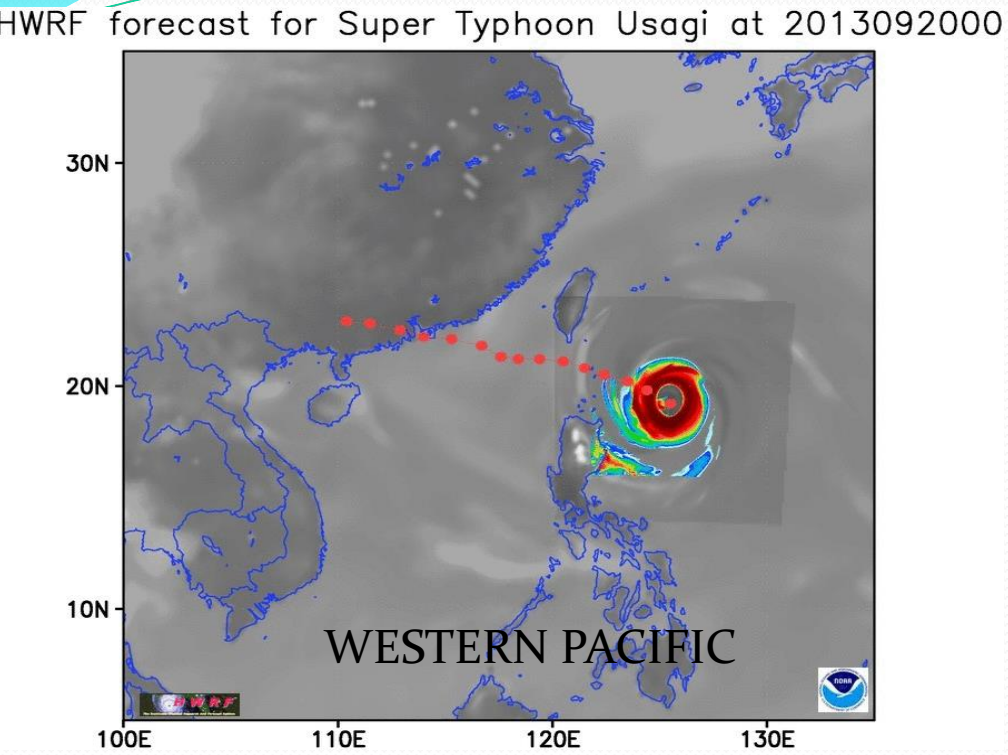
Dr. Richard J. Pasch
Senior Hurricane Specialist ,
National Hurricane Center

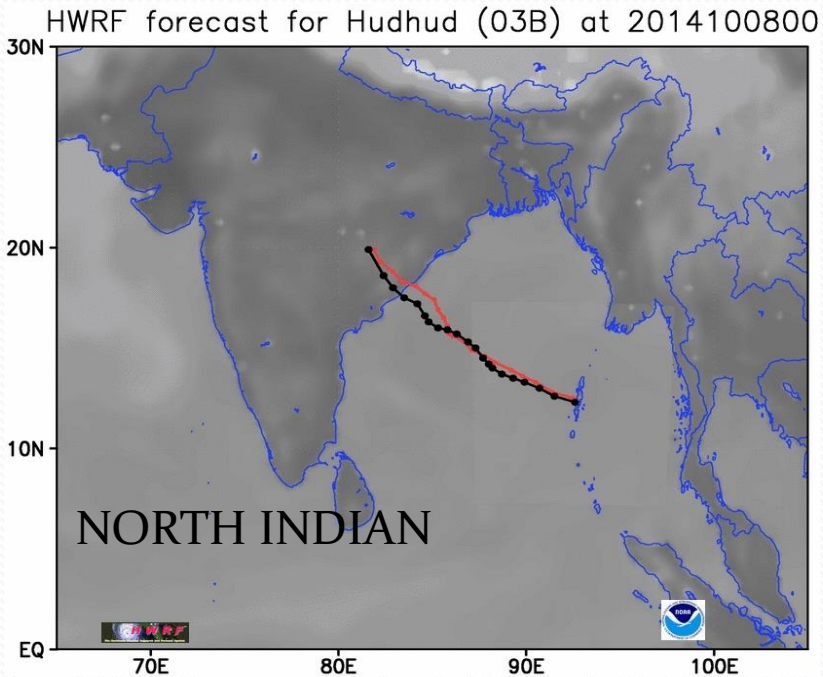
Expansion of Operational HWRF for all global tropical cyclones

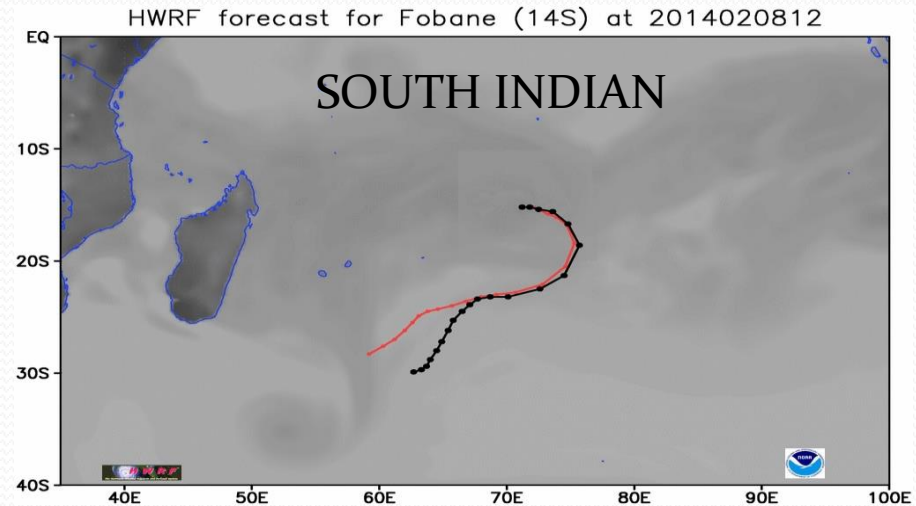
- Current operational HWRF runs in the North Atlantic, Eastern North Pacific and Central North Pacific basins, for a maximum of 5-storms as requested by NHC
- Since 2012, with support from HFIP, HWRF is run experimentally in real-time using NOAA R&D resources on Jet supercomputers, providing reliable and skillful forecast guidance to JTWC for tropical cyclones in all other basins including Western North Pacific, Southern Pacific, South and North Indian Ocean.
- JTWC has included HWRF guidance in their operational consensus forecasts.
- NWS OAA and NCEP OD have expressed interest in expanding HWRF capabilities for WPAC/SH/IO basins starting in FY15.
- Frequency of occurrence of TCs in all global basins in the past 15 years suggested that with 7-storm capability, NCEP can achieve 99.5% reliability in delivering the tropical forecast guidance products to JTWC, CPHC, NWS PR and other US interests across the world.
- **This marks a significant milestone accomplished for NCEP as a unique operational center for providing high-resolution tropical cyclone specific forecast guidance for the entire world.**
- Starting with 2015 implementation, HWRF will become truly global specialized tropical cyclone model for all ocean basins.

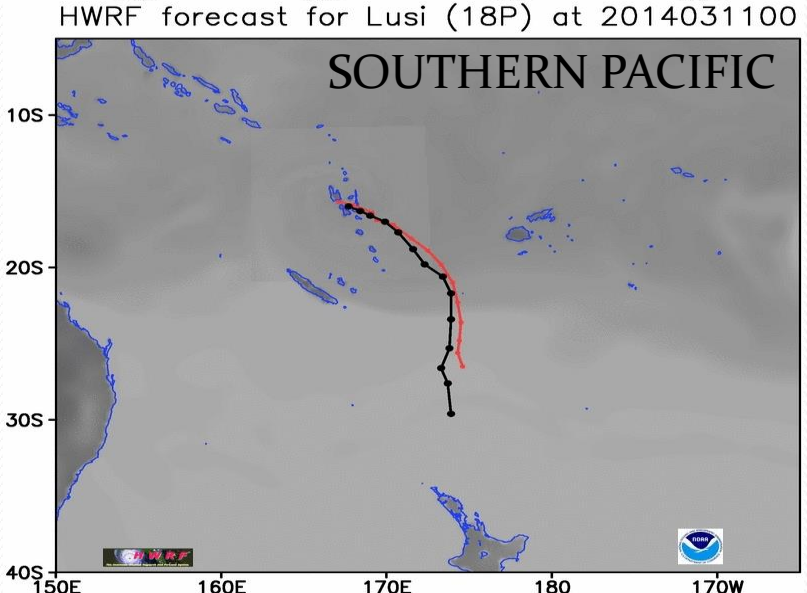
Examples of Real-Time Forecasts from 2014 HWRF

Advanced forecast products and high-definition graphics



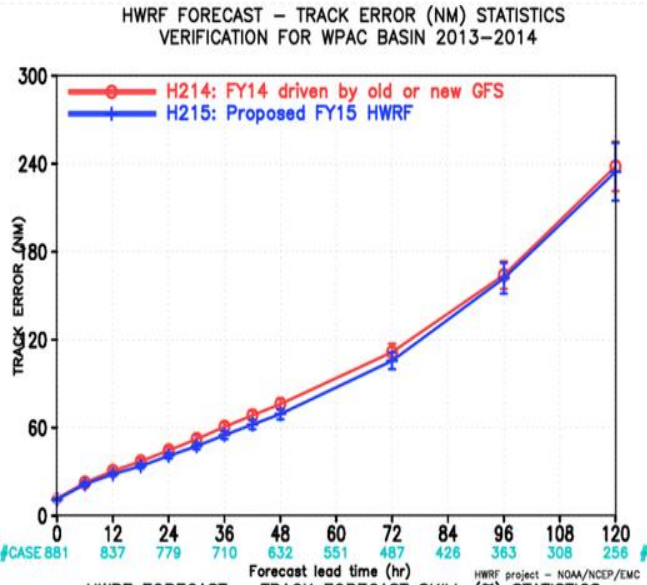


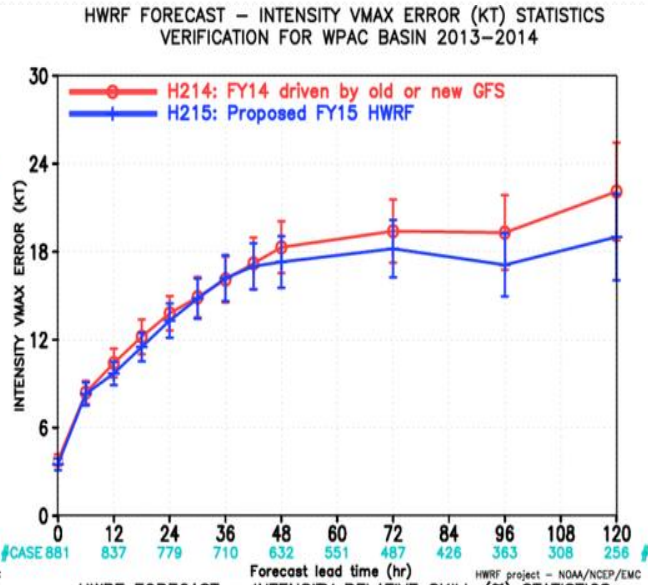


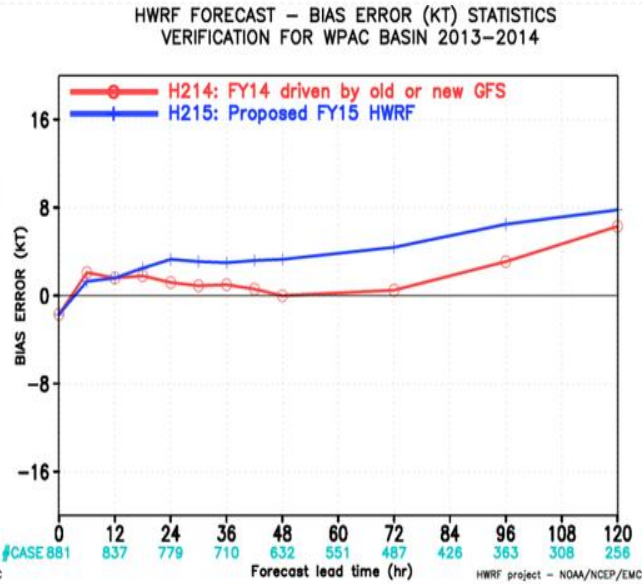


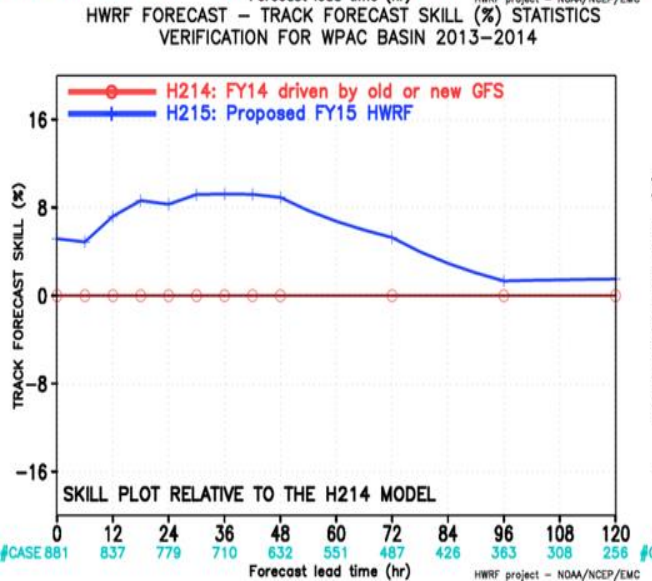
Verification for Western North Pacific, Southern Hemisphere and North Indian Ocean Storms (2013-2015)

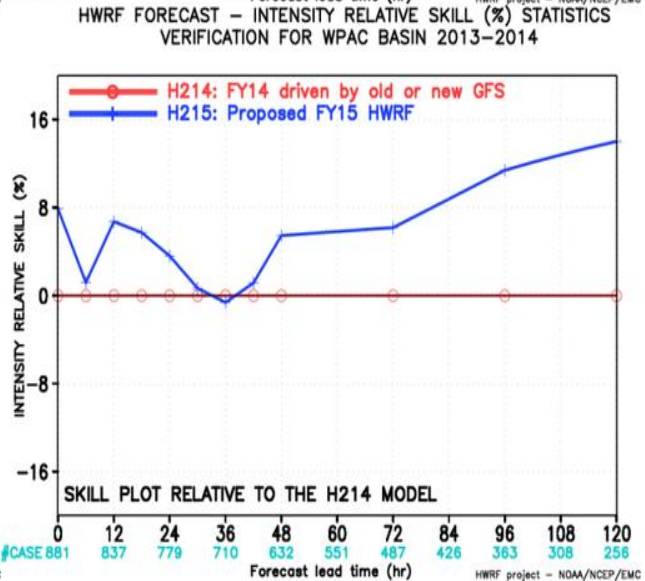
Evaluation of 2km HWRF Performance for Western North Pacific Basin H215 vs H214, 2013-2014





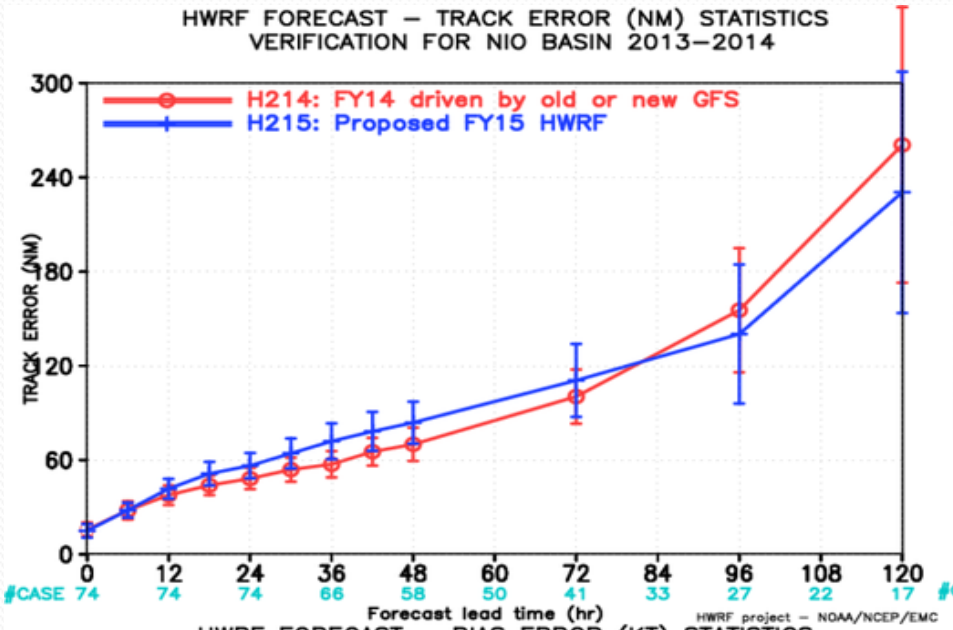


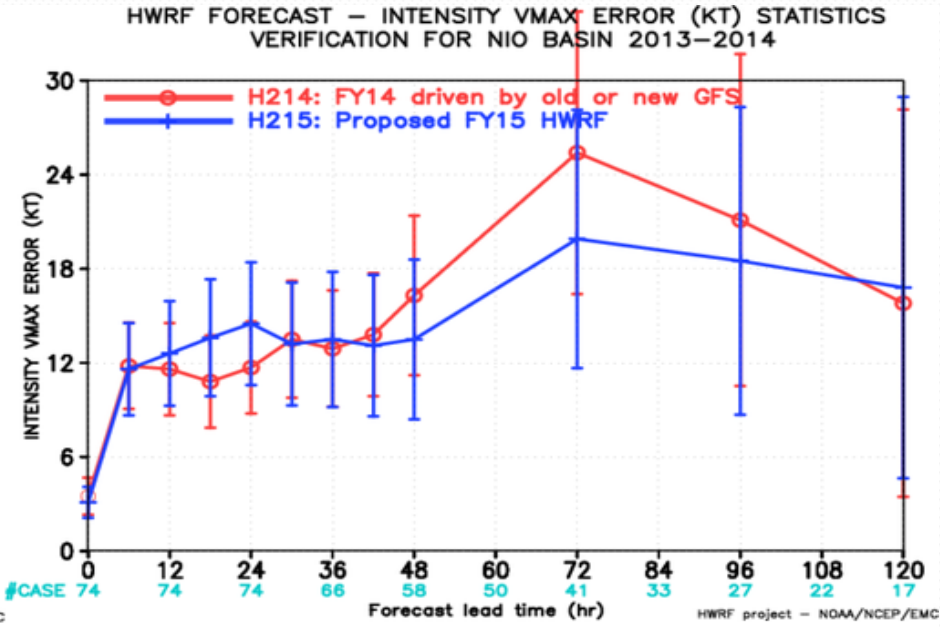


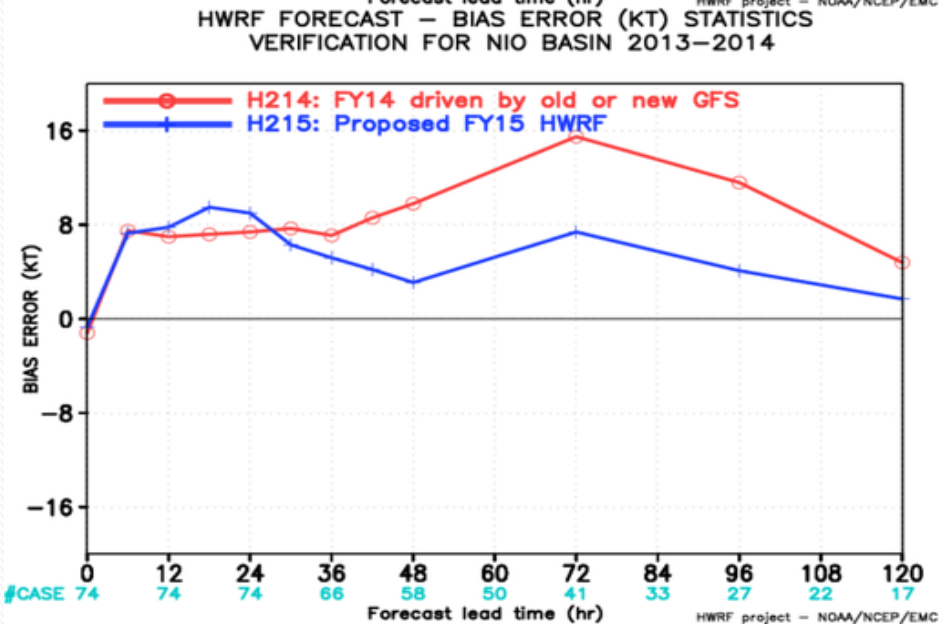


About 8% improvement in track forecasts through 72 hrs
~5-15% improvement intensity forecasts, (much improved intensity forecasts at longer lead times))

Evaluation of 2km HWRF Performance for North Indian Ocean H215 vs H214, 2013-2014

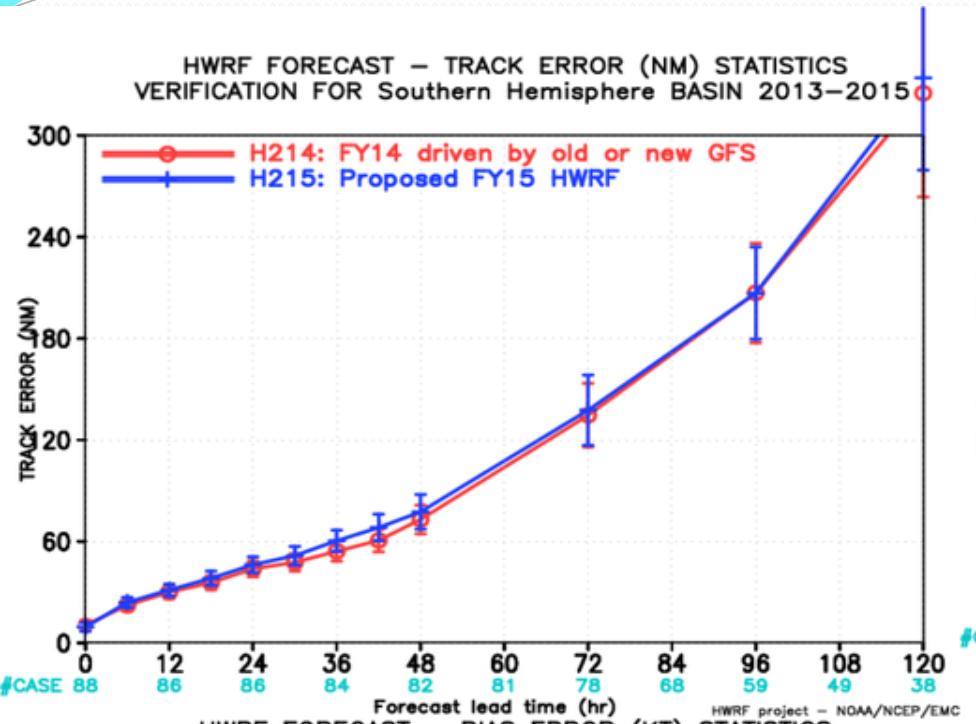


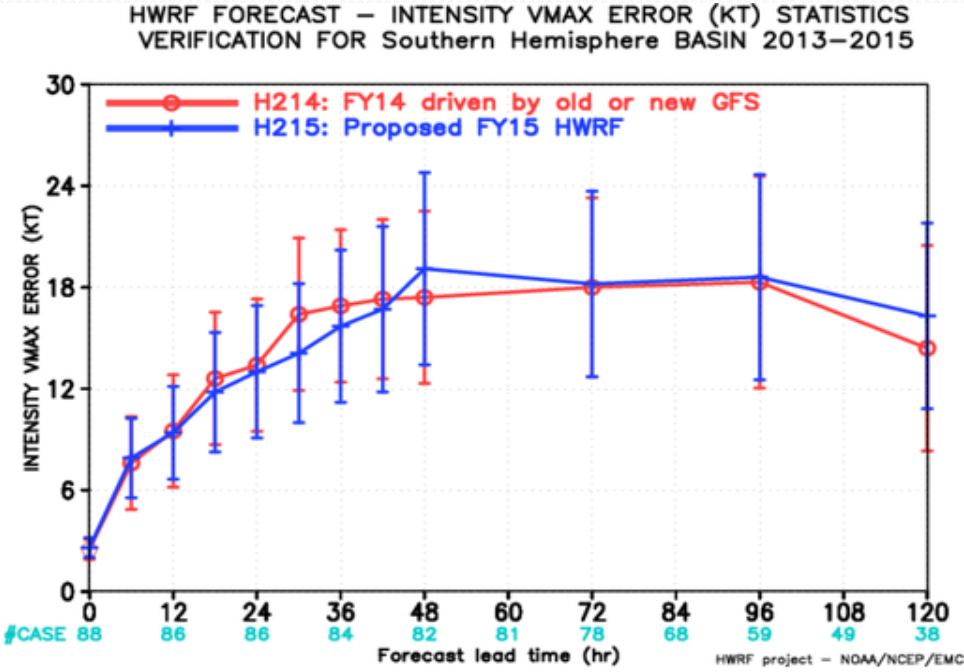


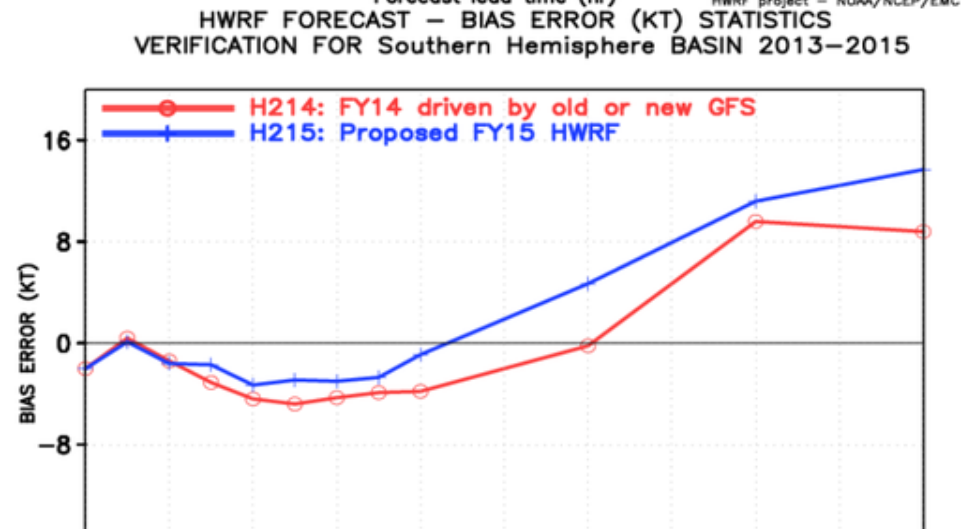


Further improvements in track and intensity forecasts for the North Indian Ocean basin, with reduced positive intensity bias

Evaluation of 2km HWRF Performance for North Indian Ocean H215 vs H214, 2013-2015

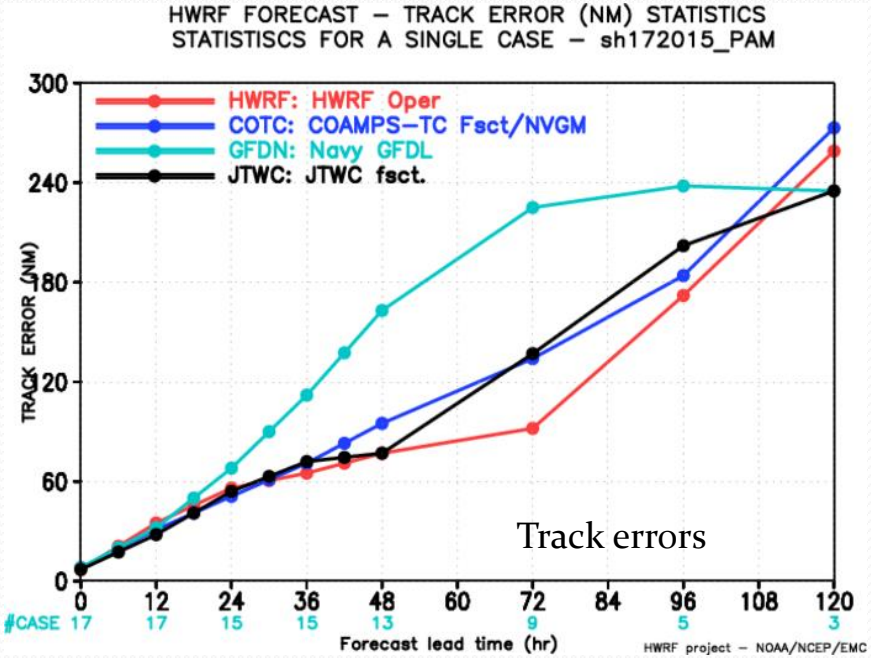


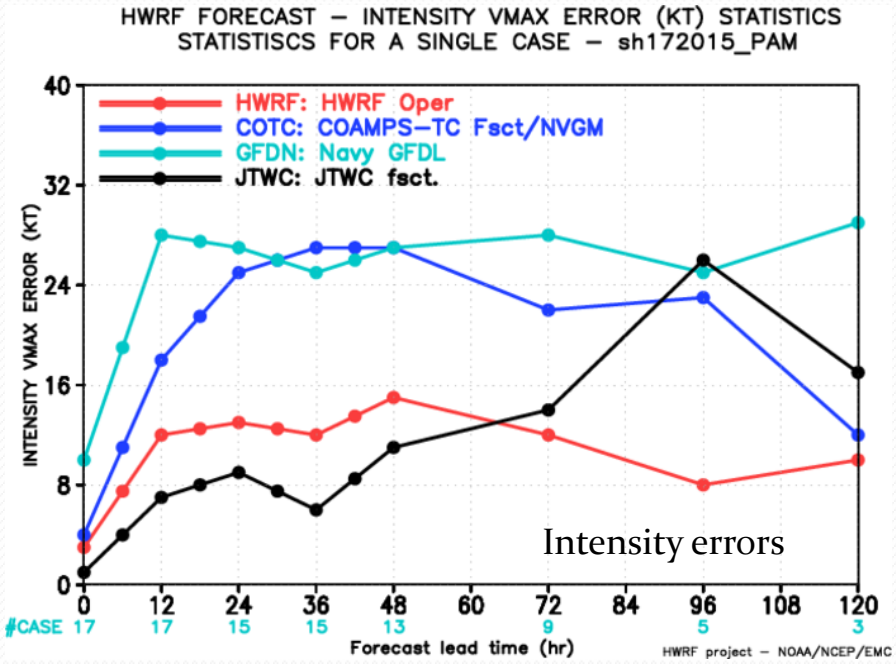




Neutral impact for the Southern Hemisphere (much less sample size due to non-availability of GFS data)

Track & Intensity Forecast Verification for Tropical Cyclone PAM 2015





HWRF track forecasts have the lowest errors compared to any other models, and better than JTWC Forecasts after day 2.

The intensity forecasts errors from HWRF are lowest compared to any other model, and are better than JTWC Forecasts at longer lead times

Endorsement from NWS PR and JTWC

"NWS PR endorse the operational implementation of HWRF for the additional basins“

---- ***Ray Tanabe, Acting Director, NWS PR***

"JTWC fully and wholeheartedly supports and appreciates the running of global H-WRF in production at NCEP. This will help ensure all United States interests receive tropical cyclone forecasts based on all available numerical model guidance”

--- ***Robert Falvey, Director, JTWC***

What it takes in operations to run 2015 HWRF

- **Resource requirements:**
  - **~2.5x compute cores (increase from 208 to 528) – 22 nodes per storm on phase II WCOSS**
  - ~7 minutes additional run-time (increase from 88 to about 95 minutes)
  - Delivery time will move from t+5.58 to ~t+6:00 for each synoptic cycle (about 2 minute max delay)
- Process optimization:
  - Process and job unification using python based scripts
- Run maximum seven storms simultaneously

Computer Resource Requirement for HWRF-ensemble Based Data Assimilation HWRF V9.0.0, Q3FY15

J-job name	Job Description	Current Resource requirement (w/ T1534 GFS)	New Resource requirement (estimate)
JHWRF_ENSEMBLE	HWRF Ensemble 6h forecast from Global EnKF analysis. 40-member 2-nest domain(18/6)	N/A 2 nodes each for 40 independent jobs for 30 min. 10 simultaneous ensemble runs will take 2 hrs to complete all 40 members	Can start at T+7:02 to be completed by T+9:30

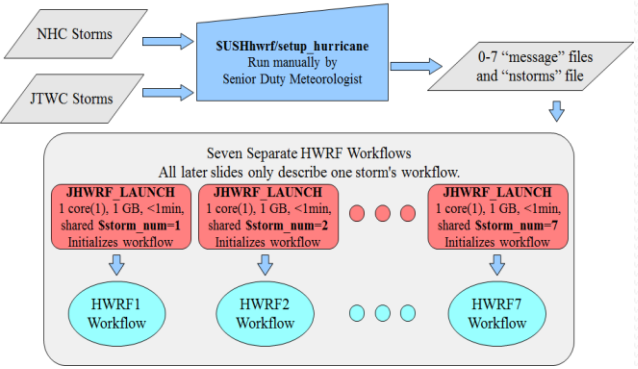
IT Testing

HWRF V9.0.0 (FY15 HWRF) is built in the same vertical structure of HWRFV8.0.11 (FY14 HWRF) implemented on WCOSS.

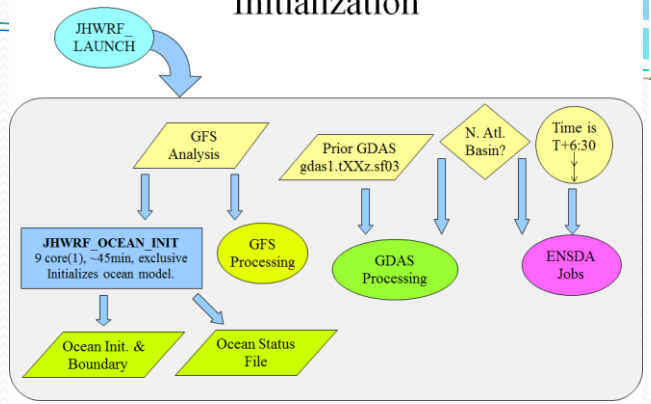
Note: Bugzilla entries are resolved and will be closed.

Test Objective	Comment
Missing GDAS EnKF members (total 80 mem)	if Nmissing >= 40, hybrid EnKF/GSI else conventional GSI
TDR (Tailed Doppler Radar) test	GSI will be done w/wo TDR for D03
Missing ICs from GDAS data	HWRF fails with proper error message
Missing BCs from GFS data	HWRF fails with proper error message
Missing previous cycle's 6-hr forecast output	HWRF runs to completion in cold start mode
Zero length data files for GSI	Initialization and analysis runs to completion
Missing input data files for GSI	Initialization and analysis runs to completion
Missing loop current for ocean initialization	POM runs to completion using climatology
Failed ocean initialization	HWRF runs in un-coupled mode
Tracker fails to identify initial storm location	Swath generator fails with proper error message
Test at least one storm in each basin	**HWRF runs to completion**
Cross dateline and Greenwich test	Make sure HWRF model and scripts properly handle the specially situations.
Bugzilla Entries	Test and confirm fixing the past issues

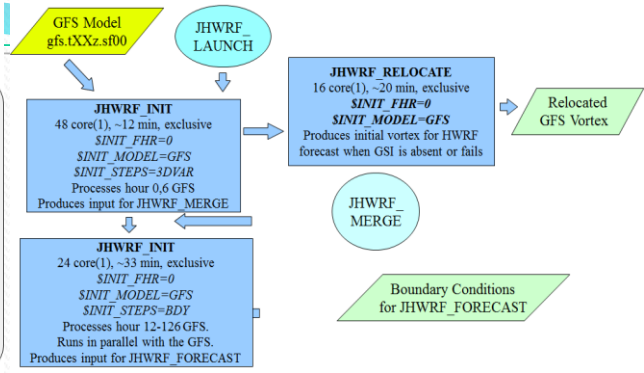
Operational HWRF Setup and Launch



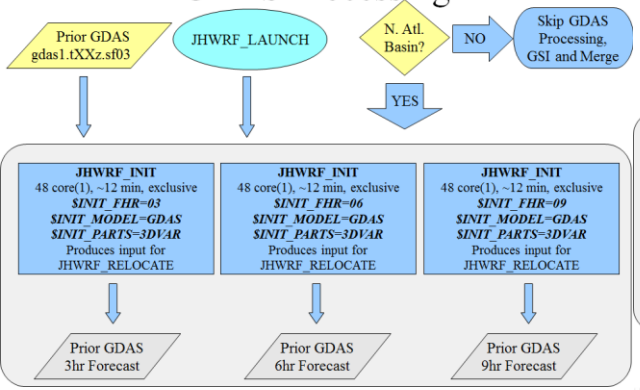
Operational HWRF Initialization



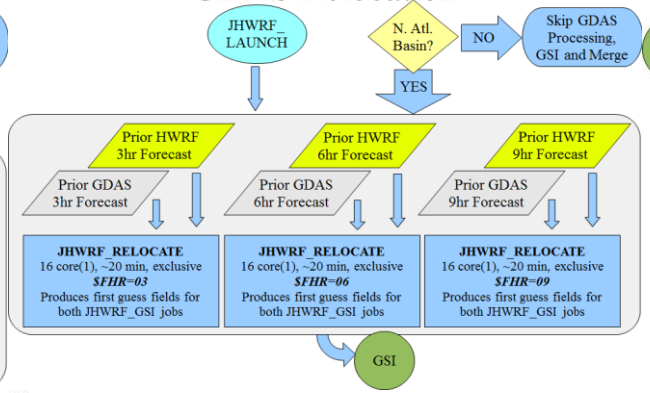
Operational HWRF GFS Processing



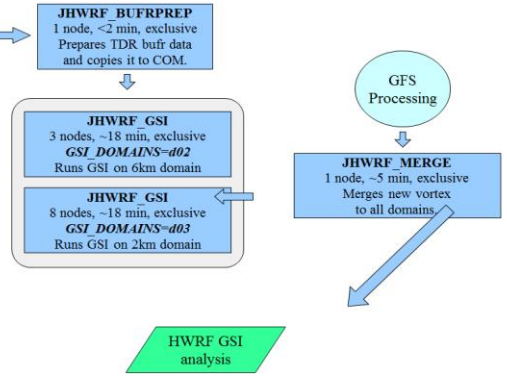
Operational HWRF GDAS Processing



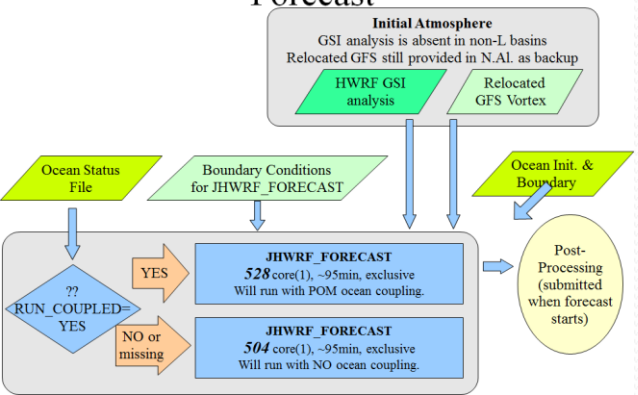
Operational HWRF GDAS Relocation



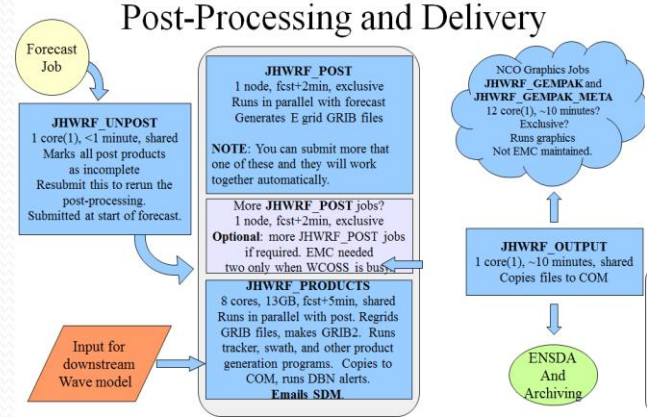
Operational HWRF GSI



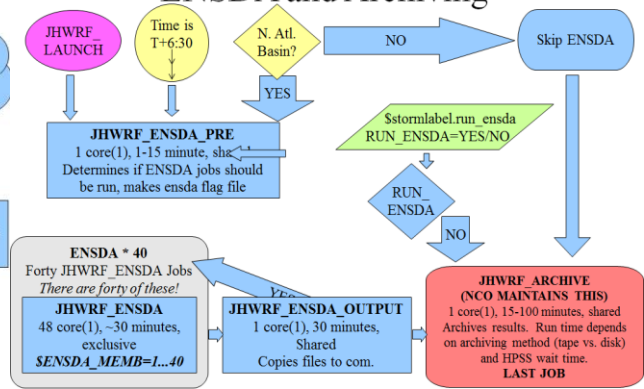
Operational HWRF Forecast



Operational HWRF Post-Processing and Delivery



Operational HWRF ENSDA and Archiving



Code Hand-Off and Release Notes

- Release Notes (includes dependencies for GFDL Ocean); HWRF/GFDL setup; triggering for HWRF ensembles
- IT Testing
- Implementation Instructions
- Workflow Diagram

https://drive.google.com/drive/#folders/0BzWMD15ttvS1fm9aSTIya09GU3BmVnpDRjFLUWtoamZVcGNUYkttWFoyOU11T3AyRWRTVWs

SVN Tag for HWRFV9.0.0 (entire system):

https://svnemc.ncep.noaa.gov/projects/hwrf/branches/hwrf.v9.0.0

New triggering mechanism for SDM to setup hurricane models; and for HWRF to run 40-member ensembles

Prioritization and selection of storms to run for HWRF and GFDL: (automated with default values, gives the flexibility for SDM to make changes through interactive process)

```
Cntr Pr SID Storm-Name -Lat- -Lon--  Vmax Pmin Penv --GFDL-- --HWRF--
-------------------------------------------------------------------
NHC   1 07L EARL       19.6N  65.2W  59.0  938 1010 message1 message1
NHC   2 06L DANIELLE   41.3N  48.0W  31.0  975 1008 message2 message2
NHC   3 08L FIONA      14.9N  49.8W  18.0 1007 1012 message3 message3
NHC   4 98L INVEST     10.3N  26.6W  10.0 1010 1012 message4 message4
JTWC  1 08W KOMPASU    25.1N 129.4E  49.0  952 1004 -CANNOT- message5
JTWC  2 07W LIONROCK   20.2N 117.6E  28.0  982 1002 -CANNOT- message6
JTWC  3 09W NAMTHEUN   25.6N 121.0E  21.0  993 1002 -CANNOT- message7
JTWC  4 93C INVEST      9.3N 171.4E  10.0 1010 1011 -CANNOT- ---NO---

Controls: [N]ext [P]rev, toggle [H]WRF [G]FDL [B]oth
When done: [S]etup models or [Q]uit without doing anything

NHC #1 = 07L EARL
  at 19.6N 65.2W moving 6.2m/s at 295 degrees from north
  wind=59m/s RMW=37km R34: NE=324, SE=297, SW=222, NW=297 km
  Pmin=938.0mbar, outermost closed isobar P=1010.0 at 463.0km radius
I see no obvious errors in the vitals data for EARL 07L.
```

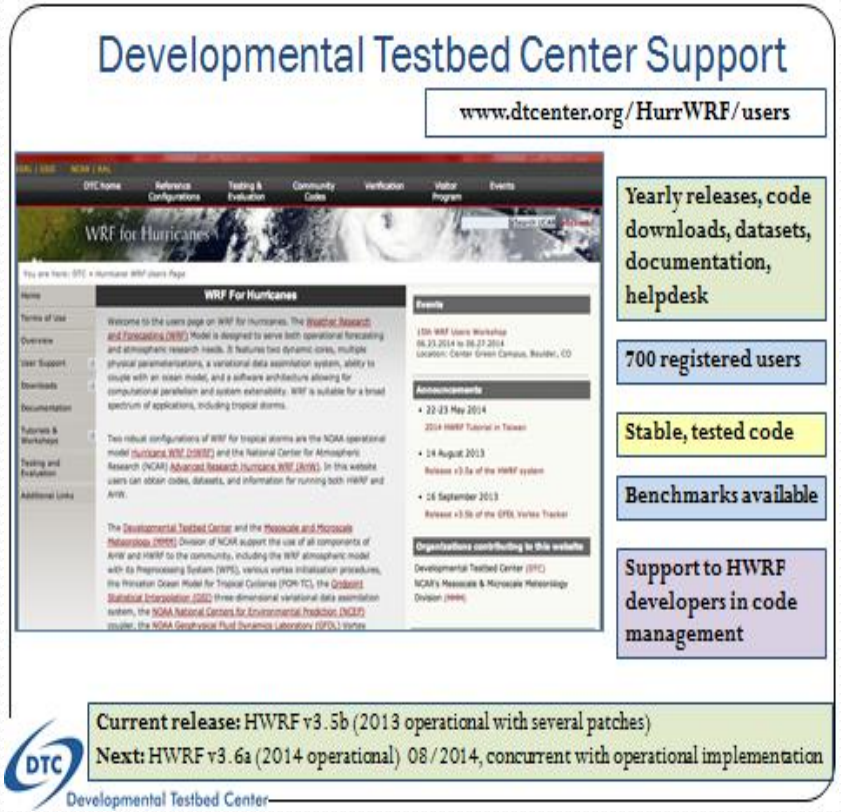
For triggering the 40-member HWRF ensembles to assimilate TDR data, AOC will send a dummy data file with Storm ID, Mission ID and other header information just before the plane takes off. HWRF scripts will read the data file and setup the workflow. Ensembles are run one cycle prior to the actual cycle where data is assimilated.

Next Steps

1. Retrospective T&E at EMC: **April 01, 2015 --- Completed**
2. Briefing to NHC: **April 9, 2015 ----- Completed**
3. NHC Evaluation and Recommendations: **April 14, 2015 -- Completed**
4. Briefing to EMC and CCB: **April 15, 2014 --- Now Completed**
5. Submission of Codes to NCO: ***April 16, 2014 --- Code Hand-Off, Submission of RFC form, release notes and flow diagram in progress***
6. TIN for HWRF : **April 24, 2015**
7. NCO IT Testing and Code Freeze: ~**May 15, 2015**
8. Briefing to NCEP Director's Office: ~**May 25, 2015 ???**
9. Implementation by NCO: **May 26, 2015**

HWRF as a unique global tropical cyclone model

Operational Real-time forecast guidance for all global tropical cyclones in support of NHC, JTWC and other US interests across the Asia Pacific, North Indian Ocean and Southern Hemisphere ocean basins



Continue the community modeling approach for accelerated transition of research to operations

NOAA HURRICANE FORECAST IMPROVEMENT PROJECT

NATIONAL HURRICANE CENTER

International partnerships for accelerated model development & research